Evaluating the Effectiveness of the Green Drop Audit Criterion in Relation to Its Link to the Enforcement Protocol in South Africa

By

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DECLARATION

I declare that this research report is my own, unaided work. It is being submitted for the Master of Science degree in Environmental Sciences at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other university.

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Olwethu Lenox Tshongweni 2023/07/13

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ABSTRACT

The Green and Blue Drop programs are incentive-based regulatory systems based on the Department of Water and Sanitation's (DWS) realization that rewarding positive behaviour is more efficient and effective than penalizing undesirable behaviour. The Green Drop was developed for the Wastewater Quality Management Regulation certification program. In contrast, the Blue Drop was developed for the certification program for the Drinking Water Quality Management Regulation (Burgess, 2021). Most municipalities have accepted them and have raised awareness about the need for better efficiency in the wastewater sector. The Sand River, in Polokwane wastewater treatment works (WWTWs), was chosen as the research area for this study. This particular river was selected based on the premise of continuous non-compliance of the wastewater treatment plant and the resulting pressure it puts on the Sand River by compromising its quality, with the DWS not having a successful way of regulating and enforcing the water user to abide by the rules of the license that has been issued. This study aims to evaluate the effectiveness of the Green Drop Program audits and assessments about their link to the regulatory system within the DWS. Additionally, a risk assessment and cumulative risk rating are used to assess wastewater discharge into the Sand River in the Limpopo Province.

Based on the observation made during the study, it appears that within the DWS organizational arrangements, the lack of coordination among the sectors (compliance monitoring, water quality management, the green drop program, and enforcement), lack of accountability, and the regulatory requirement of cooperation within DWS sectors have hindered implementation. Some of the non-compliance factors may be due to the misuse of funds meant for infrastructure development and difficulties relating to capacity, procurement, and management of the WWTWs. Moreover, DWS's absence of interactive data management systems and business processes contributes to non-compliance.

The Polokwane WWTW, directly linked to the Sand River, is overloaded and needs to comply with the Water Use Licence (WUL) conditions. For example, the 21 August 2022, this facility was found to be non-compliant by 69.01%, collectively with administration and technical conditions of the WUL issued to the facility (DWS, 2022c). In addition, this investigation discovered that the Polokwane facility, which has been operating outside of regulations for the past four years, therefore, as calculated in equation 7 could be responsible for 72.3% of the hazards to people's health, the quality of the river's water, and the aquatic ecosystem life in the Sand River in a single month.

As much as some municipalities do not perform according to the desired standards, there have been a few noticeable, well-performing ones reported in the green drop report released in 2022. These include Langebaan WWTW (90%), Riebeek Valley WWTW (97%), Gansevallei WWTW (84%), and Wellington WWTW (95%), and this illustrates that the Green Drop Certification is achievable if the municipalities follow and adhere to the Water Use Authorization (WUA) issued them (DWS, 2022b).

The DWS must integrate the internal structures or link sectors responsible for monitoring and regulating municipal water service facilities and incentivize performing facilities to improve their performance. Additionally, facilities with minor compliance issues, such as water quality, must be referred to the Water Quality Management (WQM) unit for further investigation and recommendations. However, those non-compliances of authorized wastewater treatment facilities that require regulatory attention must be referred to the compliance monitoring sector through the system for compliance monitoring. Lastly, those facilities that are not authorized must be directed to enforcement for further action. Therefore, using the Integrated Regulatory Information System (IRIS) as the umbrella body for both database and work-based information has an imperative role that can curb some of the issues faced by the DWS. Standard operating procedures (SOPs) should guide all interactions between these systems.

Keywords: Wastewater, pollution, effectiveness, Green Drop, water resource

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

CM	Compliance Monitoring
Constitution	Constitution of the Republic of South Africa Act 108 of 1996
COGTA	Cooperative Governance and Traditional Affairs
DMS	Database Management System
DEFF	Department of Environment, Forestry and Fisheries
DWEA	Department of Water and Environmental Affairs
DoRA	Division of Revenue Act 3 of 2017
ECMS	Enforcement Case Management System
EPI	Environmental Performance Index
GD	Green Drop
IDP	Integrated Development Plan
IRSI	Integrated Regulatory Information System
MIG	Municipal Infrastructure Grant
MSA	Municipal Systems Act 32 of 2000
NCIMS	National Compliance Information Management System
NEMA	National Environmental Management Act 107 of 1998
NWA	National Water Act 36 of 1998
NWRS	National Water Resource Strategy
WSA	Water Services Act 108 of 1997
WSDP	Water Services Development Plans
WSIG	Water Services Infrastructure Grant
WWTW	Wastewater Treatment Work

CHAPTER 1: INTRODUCTION

1.1. Background

Globally, there is a growing concern about surface water quality (Koklu et al., 2010). Pollutants from, but not limited to, industrial and municipal wastewater, including washed-off nutrients from agricultural land, have been compromising water quality in most bodies of water (Singh et al., 2005). In line with Edokpayi et al. (2020), the issue highlighted by Singh et. al. (2005) mentioned earlier has been and continues to be an issue for South Africa. South African municipalities need help delivering adequate water services to citizens, particularly regarding Wastewater Treatment Works (WWTWs) management. This implies that any WWTW that is not correctly operating, and discharges partially treated effluent accumulatively destroys the state of the receiving water body (Burgess, 2016).

One of the main contributing issues, based on Edokpayi et al (2020), is that the WWTWs, which comprise most of South Africa's water infrastructure, need to meet the required performance criteria. This has pressured government regulators to safeguard water resources (Edokpayi et al., 2020). This challenge for South African WWTWs is reflected in the 2018 Environmental Performance Index, where SA ranked 60 out of 180 countries, with a drop of 2 spots from 2015 where the country ranking (EPI, 2015). However, South Africa is among the countries that bid to become environmentally friendly and must find ways to improve its status. It has been ahead in finding alternatives to enhance water management (EPI, 2015). In 2008, the government, through the Department of Water and Environmental Affairs (DWEA, now known as the Department of Water and Sanitation (DWS)), considered an alternative approach to regulate Wastewater Treatment Works by introducing two programs known as the Blue and Green Drop (Burgess, 2016; Ntombela et al., 2016). The Blue Drop was created for the Drinking Water Quality Management Regulation certification program, whereas the Green Drop was created for the Wastewater Quality Management Regulation certification program (Burgess, 2021).

These programs are established to regulate compliance within Water Services Sector by governing and monitoring the set standards to achieve operational compliance through an incentive-based approach instead of the command and control-based approach only (Ntombela et al., 2016).

The Green Drop initiative has attracted increased participation from municipalities and appears to be promising a result; the Blue and Green Drop initiatives managed to raise awareness in the local sphere (municipalities) and improve the voluntary response received from the city, as high cooperation and compliance were reflected in the 2013 Green Drop analysis report (DWS, 2013). However, the program ceased to release reports post-2013, and the achieved milestone fell off since then, even though Green Drop Audits are still active in the Department (DWS).

This programme is an addition to a few subdivisions within DWS designed to regulate the nation's wastewater administration, such as Compliance Monitoring (CM) and Enforcement. The Compliance Monitoring sub-directorate is designed to manage and monitor compliance with regulation standards across all sectors. In contrast, the Enforcement Unit is intended to guarantee that a series of administrative, criminal, and civil measures are used to combat non-compliance (DWS). (2022/23 to 2024/25).

These units have a Database Management System (DMS), such as the Green Drop Programme under the Integrated Regulatory Information System (IRSI) as one of the sub-programmes, the National Compliance Information Management System (NCIMS) for Compliance Monitoring sub-directorate, and Enforcement Case Management System (ECMS) for Enforcement Unit. However, these programmes need to be designed interactively, in the sense that information is not being shared among these systems. The only interaction observed between NCIMS and ECMS is a handover button when a matter must be referred for enforcement. This design has hindrances effect in achieving prompt compliance and management of wastewater. This is because the issues handed over to enforcement are not paper trailed, but only user dependent on how much information is submitted for enforcement; hence enforcement always starts afresh for each reported case instead of using data from forefront units such as Green Drop and Compliance Monitoring. That is an existing problem within the Department, and it appears to be outside the other factors that hamper the effective management of wastewater.

1.2. Research Problem

The Green Drop Programme (GD), Compliance Monitoring (CM), and Enforcement are subunits and the unit within the Department responsible for wastewater management and regulation. However, the audits or assessment criterion for GD, CM, and Enforcement appears to achieve one goal but do not complement each other. This is due to the disconnect in information communication or regulatory findings among these sub-directorates and their DMS. This problem may hamper the achievement of successful regulation of water users in the wastewater sector and consumes time for matters to be investigated by the enforcement division.

This study aims, through various applications, to investigate the audit criteria of Green Drop and Compliance Monitoring and their link to the active enforcement investigations. Furthermore, the study sought to suggest, through the findings, more effective communication within DWS internal sub-directorates and linkage of the Database Management Systems (DMS) for effective regulation. For this study's purpose and scope, the Green Drop certification programme was assessed with other regulation systems, such as NCIMS and ECMS, designed to manage wastewater quality within the Water and Sanitation Department.

1.3. Aims and Objectives

1.3.1. Aim

This project's primary objective was to recommend the best possible linkage option for these DMS applications using Green Drop Programme as the baseline system. This study evaluated the effectiveness of communication (link) between the Green Drop Programme, Compliance Monitoring and Enforcement divisions, and how this enabled effective regulation of wastewater in the municipal sector. This was supported by assessing the effluent discharge impact on the Sands River, below the discharge point of Polokwane WWTWs in Polokwane Province (replaced Riverview WWTW discharge point into Olifants River in Mpumalanga, which has a gap in available water quality data for the selected assessment period for the study).

1.3.2. Objectives

- To determine the tools that support the effective water resources management, protection, and regulation of wastewater.

- To determine the contributing factors, effective regulation of wastewater, and other related significant factors.
- To evaluate the effects of wastewater discharge from WWTWs into water resources in selected South African river systems and detail water quality indicators.
- To determine the impact of effluent discharge by a WWTW in the vicinity of Polokwane City Area in Polokwane Local Municipality in the Sands River (which replaced Riverview WWTW discharge point to the Olifants River at eMalahleni Local Municipality in Mpumalanga Province due to a gap in historical water quality data).

1.4. Research Question

The Green Drop Programme (GD), Compliance Monitoring (CM), and Enforcement are subunits and the unit within the Department responsible for wastewater management and regulation; however, the audits or assessment criteria for GD, CM, and Enforcement aim to achieve one goal but don’t complement each other. This is due to the disconnect in information communication or regulatory findings among these subdirectories and their DMS. This problem hampers the achievement of successful management and regulation of water resources by preventing them from being polluted by wastewater treatment facilities through the discharge of partially treated effluent, and it consumes time for matters to be investigated by the enforcement division. Therefore, this study seeks to find out: what is the cause of the disconnect between these units and their systems?

1.5. Research Hypothesis

Improved performance of wastewater treatment plants through effective management and regulation of water resources will enable improved water quality in rivers.

1.6. Limitations of Study

The primary study project limits are the need for studies focusing on the Department of Water and Sanitation's database management systems and the use of pre-existing and non-vetted water quality data collected by clients at their discretion with only one consideration from the authority side.

CHAPTER 2: LITERATURE REVIEW

2.1. BACKGROUND

Viewing contributors of contamination to water resources from a global perspective, Breitenmoser et al., (2022) looked at the barriers and drivers that are perceived in administering wastewater treatment and recycling in India. In 2021, Breitenmoser and the team highlighted that the significant point is the persistent water shortage, a driving factor for wastewater treatment and reuse, which demands a substitute for the water supply in that country. However, in a different outcome, it was discovered that the most significant obstacles were the absence of enforcement of pollution monitoring and control, the overarching direction for integrated water resource management, and the insufficient cooperation between relevant government entities and central and state water authorities (Breitenmoser et al., 2022). This scenario is familiar to South Africa between government spheres, Catchment Management Agencies, and water boards. Given the facts mentioned earlier that prevent wastewater reuse owing to problems such absence of pollution monitoring, regulation, and enforcement, it was determined that it is necessary to combine current water and wastewater policies and programs into the National Water Framework as a canopy of general principles, managing water matters by the Central Government, the State Government, and local governing bodies in that country (Breitenmoser et al., 2022). Furthermore, Wang et al. also looked at the idea of highlighting the significance of appropriate management strategies to enable the protection of the ecological health of the receiving rivers (Wang et al., 2021).

A similar issue was noted in a study conducted in the Northwest Tibetan Plateau (China) on the effects of discharge from municipal wastewater treatment facilities on the composition and organization of the river's microbial community (Wang et al., 2021). The same was true in other countries like Spain, where Hospido and others disco back in 2004 that the performance of WWTWs was a problem and established an alternative to reduce the environmental impact (Hospido et al., 2004). This was considered for future legislation that sludge disposal and water discharge on land and using a biological aerobic treatment in conjunction with a nitrification-denitrification system to remove nitrogen suggests a significant reduction in the environmental effect. (Hospido et al., 2004). This implies that most developed countries have recognised the transformative legislative intervention to deal with the performance of Wastewater Treatment Works.

These cases experienced in India and China are familiar to South Africa and date back to 2010. For example, Mema 2010 pointed out the issue of poor maintenance of wastewater treatment works as an issue at hand. Still, it is different regarding the absence of a response from the various local and national government domains. He further mentioned that it is unsound for government to focus on building more wastewater facilities without dealing with the underlying factors which failed infrastructure in our country. This came with the notification that the South African nation has a solid stance to address this issue; these measures must be transformed from paperwork into actual implementation (Mema, 2010). Similarly, Edokpayi et al., (2017) also evaluated the problems of failing wastewater treatment facilities. Among things, they noted that poor operations, the inability to adequately monitor compliance, the capacity of current facilities being overloaded, and the deficiency of finance for wastewater treatment are South Africa's leading causes of water pollution (Edokpayi et al., 2017, and Ntombela et al., 2016). According to these authors, water and environmental regulations must be strictly enforced to protect the environment and the health of those who still rely on surface water supplies. Edokpayi et al., (2017). Ntombela et al. (2016) say that this problem results from a series of instances where this nation's laws, regulations, standards, and norms about water resources have been disregarded (Ntombela et al., 2016).

Numerous insights provided by various authors indicate that the lack of effective regulation of wastewater treatment facilities lies with legislative implementation and enforcement, which appear to be failing over the years. Despite introducing new project initiatives (such as Green and Blue Drop programmes and scholarly recommendations) to aid in the continuous degradation of water resources due to partially or untreated effluent from WWTWs, in this case, Municipal. For example, in 2021, Pereaoa and others suggested a technique called toxicity evaluation which enables the management of the municipality to take necessary procedures for pollution control; and lessen several ecotoxicology issues before the discharge of effluent to the water resources (Pereaoa et al., 2021). This adds measures from the legislative framework, project-based initiatives, government structures, and financial support systems. Section 24 of the Constitution's "Environment" chapters and other supporting legislative provisions all make the Bill of Rights mandate for achieving this goal explicitly. Therefore, this country constitutes a diverse legislative provision to deal with the contributing facts that leads to the non-compliance of WWTWs and their discharge of partially treated effluent to the receiving rivers.

2.2. WATER RESOURCE PROTECTION SUPPORT TOOLS

2.2.1. Legislative Context

South Africa, following 1994, has developed legislations, norms, standards, policies, strategies, and guidelines specifically to deal with water resource protection and management and environmental management. In the broader perspective of the environment, these statutes are designed to manage, use, control, develop and protect water resources and the environment at large. Regarding this research report, safeguarding water resources is a crucial component of water resources management, which is where the focus lies.

2.2.2. Republic of South Africa's Constitution ("The Constitution")

Human dignity, human rights and freedom advancement and equality achievement, constitutional supremacy, and the rule of law are among other values on which the democratic state of South Africa is founded (s.1(a &c) of RSA, 1996). Second, everyone is guaranteed a right to an environment that is not injurious to their health or well-being, and that is protected for the benefit of both current and future generations via reasonable legislation and other measures that aim, among other things, to prevent pollution and ecological deterioration (s.24 of RSA, 1996). Once more, Section 2 guarantees that the Constitution's requirements are met and deem any behaviour that conflicts with them illegal (s.2 of RSA, 1996); these obligations for national, provincial, and local government within its jurisdiction include duties in Section 41(1) (b-d) to, (b Assure the welfare of the Republic's citizens; (c) provide efficient, responsible, transparent, and cogent governance for the totality of the Republic; and (d) show loyalty to the Constitution, the Republic, and its citizens. (RSA, 1996, s. 41(1) (b-d)).

Moreover, schedule 2, sections 3 and 5 of the constitution allow establishing these requirements. According to the constitution, members of the cabinet (also known as "ministers") and members of the executive council (also known as "MECs") of provincial governments must express their allegiance to the constitution and the people of South Africa, as well as their commitment to "perform the tasks of (their) offices" by taking an oath or making an affirmation. In equal force, these Constitutional provisions apply to local government, and it requires that a municipality strive, within its financial and administrative capacity, to achieve its objectives set out in the Constitution (s.152(2) (b-d) of RSA, 1996).

These obligations in terms of the Constitution are carried out using delegated legislation specifically designed for water resources protection and management in the country. These delegated legislations are the National Water Act 1998, Water Service Act 1997, Municipal Systems Act, White Paper (National Water Policy), regulations, Strategies, guidelines, and other related environmental legislations. The lead authority about the former is the Department of Water and Sanitation (DWS).

2.2.3. National Water Act, 1998 (Act No. 36 of 1998) ('the NWA')

The Constitution's powers to manage water resources are vested in the National Government through the Department of Water and Sanitation. This responsibility is undertaken using the National Water Act of 1998 to address the water resources such as rivers, streams, dams, and groundwater (de la Harpe and Ramsden, 1998). The Act entails the aims, objectives, and rules on how surface and groundwater should be safeguarded, utilised, improved, conserved, managed, and regulated for the benefit of all people (de la Harpe and Ramsden, 1998).

The National Water Act's purpose is to ensure that the nation's water resources are protected, used, developed, conserved, managed, and controlled in ways that consider, amongst other factors, (a) meeting the basic human needs of present and future generations; (b) promoting equitable access to water; (d) promoting the efficient, sustainable, and beneficial use of water in the public interest; (g) protects aquatic and associated ecosystems and their biological diversity; (h) reducing and preventing pollution and degradation of water resources; (i) meeting international obligations; and promoting dam safety" (s.2 of NWA, 1998). This mission is carried out in line with section 3 provisions of the NWA, which give the National Government, operating through the Minister of DWS, the power to control and ensure that water resources are conserved, used, safeguarded, managed, controlled, and developed equitably and sustainably, for the benefit of all people, and in compliance with the mandate of the constitutional provision (s.3 of NWA, 1998).

After consulting with the appropriate parties, the DWS released the National Water Resource Strategy (or "the NWRS") as the framework for the nation's preservation, utilization, development, conservation, management, and control of water resources t the national, provincial, and local levels. This was done in terms of Chapter 2 of the NWA. The NWRS must discuss international commitments and rights, present and future water needs projections goals for improving water quality through a classification system (s.6 of NWA, 1998). Then, in terms of section 7, when exercising or carrying out any duties under the NWA, the National DWS, organs of state, and water management institutions must give effect to the NWRS.

The Act, provision by Section 151 of Chapter 16, lists the activities and omissions that, whether by intentional or negligent behaviour, have the effect of contaminating or have a high possibility of polluting a water resource and are therefore unlawful, along with the corresponding penalties (s.151 of NWA, 1998). Accordingly, when harm, loss, or damage caused by the offense for which a person was convicted is established, the person or people who incurred the injury, loss, or damage may be awarded monetary damages (Section 152 of NWA, 1998) (s.153 of NWA, 1998).

2.2.4. Water Services Act 108 of 1997 ('WSA')

The Constitution also empowers municipalities, which are part of the local government, authority to oversee water services (de la Harpe and Ramsden, 1998). The guiding legislation to undertake this responsibility is the Water Service Act 1997, which provides water services such as portable water predominantly; households and other water users receive sanitary services (de la Harpe and Ramsden, 1998).

All branches of government have a clear obligation under the Water Services Act's preamble to ensure that sanitation and water distribution services are delivered fairly, effectively, and sustainably. Further, the WSA preamble affords the national government custodial rights over the nation's water resources (WSA, 1997). According to section 11(1) of the WSA, a water service authority (municipality) in its jurisdiction provides progressive, effective, economical, and affordable access to water services for all current and prospective consumers. So, according to Section 1 of the Act, "water services" are defined as "services associated with water supply," which include the abstraction, transportation, treatment, and distribution of drinkable water, as well as water intended to be converted to potable water or water for commercial use but not for industrial use (s.1 WSA, 1997). On the other hand, sanitation services are described in the same section as the collection, removal, disposal, or purification of human excreta, domestic wastewater, sewage, and effluent resulting from using water for commercial purposes (s.1 WSA, 1997).

Nonetheless, Section 63 of the Act, which enables the province or the national (i.e., DWS) to interfere when a water service authority has successfully carried out any prescribed function by or under the WSA, gives effect to Section 139 of the Constitution (s.63 WSA, 1997). Therefore, upon failure by the water service authority to provide for the above water services, section 73 of WSA provides powers the Minister of the Water and Sanitation Department has the authority to intervene. This intervention is supported by the general ministerial rules outlined in section 73(b)–(j) of the Act (s.73 WSA, 1997). Aside from this involvement by the federal or provincial government, the municipal systems act 32 of 2000, among other sections, requires the municipality's management to ensure resources are available to ensure that the municipality effectively performs any mandated activity by or under the WSA.

2.2.5. The Municipal Systems Act 32 of 2000 (referred to as "the MSA")

The MSA requires a municipal council under Section 4 to work with other state organs to "progressively realise the fundamental rights guaranteed by Sections 24, 25, 26, 27 and 29 of the Constitution, within the municipality's financial and administrative capacity and taking into account practical considerations" (s.4 MSA, 2000). Also, according to Section 43 of the Act, municipalities must respect both the rights of their inhabitants and those guaranteed by the Bill of Rights for others when exercising their legislative and executive powers (s.4(3) MSA, 2000).

2.2.6. Act 107 of 2008 Concerning National Environmental Management (NEMA)

Like NWA, NEMA mandates that international obligations linked to environmental issues be fulfilled in the national interest. It also stipulates that the NWA is a specific Environmental Management Act, establishing DWS as a member of the Environmental Management Inspectorate, and it creates a framework for the environmental inspectorate (NEMA, 2008). All state organs must also have a five-year environmental management and implementation plan that adheres to NEMA's goals (SAHRC). This requirement applies to national and provincial departments (SAHRC, 2021).

These management plans upon its implementation are intended to “(a) coordinate and harmonise the environmental policies, plans, programmes and decisions of the various national departments that exercise functions that may affect the environment or are entrusted with powers and duties aimed at the achievement, promotion, and protection of a sustainable environment, and of provincial and local spheres of government, in order to, (i) minimise the duplication of procedures and functions; and (ii) promote consistency in the exercise of functions that may affect the environment; (b) give effect to the principle of cooperative government in Chapter 3 of the Constitution; (c) secure the protection of the environment across the country as a whole; (d) prevent unreasonable actions by provinces in respect of the environment that are prejudicial to the economic or health interests of other provinces or the country as a whole; and (e) enable the Minister of Environment, Forestry and Fisheries to monitor the achievement, promotion, and protection of a sustainable environment.” (SAHRC, 2021). Furthermore, many control mechanisms NEMA provides enable national-level measures to ensure environmental protection. (SAHRC, 2021).

2.2.7. Waste Act 59 of 2008: National Environmental Management (NEM: WA)

Section 65(1) of NEM:WA states, despite the authority granted to the Minister responsible for the environment or MEC by or under this Act, the Minister responsible for water may exercise any control given to them by Sections 19, 53, and 155 of the NWA about anybody who violates or disobeys any requirements of a waste management license, a remediation order, or measures specified in terms of Section 38(3) that may have an impact on a body of water.

2.2.8. South Africa's National Water Policy White Paper, April 1997

The white paper's Section 6.3.1 highlights the reliance on water resources for certain silent services and providing water for domestic use, agriculture, and industry. These quiet services include purification and removal of waste, subsistence and commercial supply of plants and food, water retention and storage, asportation of recreational and ecotourism opportunities, and biodiversity conservation through habitat maintenance. As a result, given that these services are advantageous for using water resources, if water resources are used excessively or deteriorate owing to the effects of waste discharge and land use in the near term, they may no longer be able to sustain use in the long term. That is why it is vital to protect the water resource to ensure sustainability (NWP: WP, 1997). Currently, the country is sitting with a diverse legislative framework to achieve this goal of the white paper; however, things are deteriorating regarding protecting the water resources, especially municipal effluent discharges.

2.2.9. National Water Resource Strategy (NWRS3)

To foster socioeconomic development and growth for the benefit of present and future generations, the strategy is intended to safeguard and manage water resources to provide equitable and sustainable access to water and sanitation services (DWS, 2022b). In terms of achieving the development goals of the national government, it is the primary tool for managing water throughout all divisions. The NWRS-3 is a tool created for all departments and stakeholders who utilize and have an impact on a nation's water resources (DWS, 2022b). It responds to the defining intents of the strategy as developed within the prescripts of the NWA and activities that are then brought up for funding and implementation in the National Water and Sanitation Master Plan (NW&SMP) (DWS, 2022b).

Once put into effect, the National Water Resource Strategy's goal is to facilitate the proper management of the nation's water resources by ensuring that a framework is in place that allows for the control, conservation, use, development, management, and protection of those resources across the board; providing a framework for water resource management at the local, regional, and catchment levels as well as in specific water management areas; ensuring that the regulation for water and sanitation organization is strengthened; providing information on all aspects of water resource management; identifying opportunities and constraints for the development of the water sector; and implementing the solution and innovative solutions.

2.2.10. Guidelines for South African Water Quality (TWQR)

To ensure that the fundamental goal of the National Water Act, 36 of 1998, is accomplished, the Department of Water and Sanitation (DWS, which was DWAF at the time) took the initiative to draft the water quality guidelines within the provisions of this act. This work aimed to make it possible for all essential participants in this complex system to operate with due diligence to achieve this goal by maintaining water quality for human use and safeguarding the health of the aquatic environment (DWAF, 1996). These recommendations serve as an enabling foundation of knowledge regarding water quality determinants for various water uses to ensure the well-being and safety of aquatic ecosystems (DWAF, 1996).

2.3. Financial Support to Water Service Authorities

The Regional Bulk Infrastructure Grant (RBIG) and the Water Services Infrastructure Grant are programs the Department of Water and Sanitation has in place to assist local governments (WSIG). These Departmental systems were created expressly to assist the Local Government with infrastructure maintenance, operations, and upgrades. These methods add to Municipal Infrastructure Grant (MIG) (MIG).

2.3.1. Municipal Infrastructure Grant (MIG)

Grant for Municipal Infrastructure is a crucial objective to fund essential services for all municipal infrastructures to provide the fundamental requirements of common inhabitants who rely on municipal services including roads, electricity, water, sanitation, and recreation (OUTA, 2017). The MIG is allocated directly to the municipalities from the national treasury through the Division of Revenue Act's provisions (DoRA). The funds are issued with specific objectives to eradicate municipal essential infrastructure backlog that examines low-income households, microbusinesses, and social service organizations working with underprivileged populations (OUTA, 2017). However, it has been noted that municipalities allocate less or nothing for wastewater facilities. This could be due to several reasons, which include but are not limited to the fact that money allocated to municipalities by the national treasury is not sufficient, priorities set out by the municipality, or nothing is allocated because there are other grants available to support WWTW such as the RBIG, and WSIG. However, despite having all these grants, wastewater treatment facilities are aging, some have poor operations and maintenance, and in a nutshell, what you hear from the municipal wastewater treatment facility management is that the municipality needs more money, and it ends there.

2.3.2. Regional Bulk Infrastructure Grand (RBIG)

The RBIG supports the DWS-approved regional bulk water and sanitation infrastructure by financing its social component (OUTA, 2017). The award is intended for large-scale projects within one municipality or those that span many municipalities (OUTA, 2017). This award is the large-scale infrastructure required to provide for individual houses' reticulated water and sanitation service, as well as any feasibility studies required for planning or management (OUTA, 2017). These funds are distributed in direct and indirect components; for example, if the municipalities are well-capacitated to conduct some projects themselves, the direct grant form is utilised (OUTA, 2017). If the municipalities are incapable, then an indirect grand component is used, where the DWS takes the responsibility to implement those projects in terms of DoRA (OUTA, 2017).

Department of Water and Sanitation endorses these projects subject to certain restrictions set by DoRA; if not, DWS suggests those projects that require significant funding, and the National Treasury approves them (OUTA, 2017). Projects must be included in the municipal Integrated Development Plan (IDP) and Water Services Development Plans to be funded (WSDP). Second, there needs to be a connection between projects supported by Municipal Infrastructure Grants and Water Services Infrastructure Grants (OUTA, 2017).

2.3.3. Water Services Infrastructure Grant (WSIG)

WSIG is intended to expedite the service delivery process to areas that lack access to essential services (clean water and sanitation) (OUTA, 2017). Like RBIG, this grant is given out by the Department of Water and Sanitation for various projects, including developing new infrastructure, improving already-existing water schemes, or renovating (OUTA, 2017). Similarly, with RBIG, this grant is distributed directly and indirectly. For example, the direct grant form is utilized if the municipalities are well-capacitated to conduct some projects themselves (OUTA, 2017). In the event the municipalities are not capable, an indirect grand component is used, where the DWS takes the responsibility to implement those projects in terms of DoRA (OUTA, 2017), or the National Department (DWS) may take it upon itself and capacitate the municipality with the required skill to equip the municipality to be able to implement future projects themselves (OUTA, 2017).

Reflecting on the financial management and distribution of support grants among other things it was discovered that especially on RBIG distribution, it needs more planning, and it also needs more project management and engineering capacity and skills (OUTA, 2017). As an illustration, the auditor general (AG) expressed grave worry over the RBIG's selection of projects based on political preferences, disregarding planning reports, the availability of local resources, and preliminary feasibility assessments

(OUTA, 2017). Similarly, AG revealed that DWS needed more certified project managers who are essential to the execution of such a significant capital program with various projects spread out over all nine provinces; neither had a retention policy and succession plan. As a result of inadequate retention and succession planning, the department sometimes needed help keeping technical professionals (OUTA, 2017). (OUTA, 2017).

In addition to this, DWS internal structures, such as infrastructure development (the unit responsible for grants such as RBIG), refrain from consulting with other regulatory departments. For example, in compliance, the team would go on-site to do an audit only to be told that DWS said they would sponsor the refurbishment of our (WSA) wastewater treatment works, and until then, there is nothing can be done. This scenario compromises the compliance monitoring function as most water users (WSA) use the excuse that the municipality does not have funds to operate and maintain wastewater treatment works or to refurbish them. They can only do that if the DWS approve their fund application and if they give enough money as in what they apply for. Yet, MSA mandates water service authorities to ensure that resources are available to carry out its water services duties. This is one of the first experiences on the compliance monitoring audit conducted in Polokwane Wastewater Treatment Works, which receives about 50 ML/day and 70-85 ML/day during the rainy season on a facility designed to cater to 25 ML/day. This facility was awarded RBIG to build a new facility (Regional WWTW) 20 ML/day; the project started in 2014 and is projected to be completed in 2025. Yet even the 20 ML/day is the reduced designed capacity because the initial design capacity applied for was 40 ML/day, but for some reason, that has to do with a deficit of funds has led to that capacity reduction.

2.4. Organisational Support

Considering the above aiding factors to manage water resources and curb the pollution resulting from various contributing factors, DWS is the institution vested with the authority to put the above-aiding factors into action. The department has chief directorates (CD) responsible for different functions. The one specifically accountable for adherence to legislation is CD: Water Use, Compliance Monitoring, and Enforcement. Within this CD are various directorates; however, the ones responsible for monitoring compliance and enforcement where necessary are Water Service

Regulation (previously a chief directorate for green and blue programmes directorates) and Water use, compliance monitoring, and enforcement.

2.4.1. CD: Water use, compliance monitoring, and enforcement

The directorate develops necessary measures to improve the regulatory function (norms, rules, and regulations), as needed, and coordinates and reports on compliance monitoring operations conducted nationally. It also offers the technical information and training required to meet the directorate's and the chief directorate's goals of water use, compliance monitoring, and enforcement (DWS, 2021).

2.4.2. Compliance Monitoring

Compliance monitoring through a regulatory authority directorate deals with planned and scheduled monitoring where all authorization conditions are assessed for compliance (DWS, 2021). The water user can provide the department with supporting documentation that they obey the Water Use Authorization (WUA) conditions issued throughout this procedure. Compliance monitoring is generally conducted throughout the lifetime of an authorised facility through a planned and organised systematic schedule (DWS, 2021).

This process includes activities related to the information collection, review, and analysis and seeks to determine compliance; it is a vital base element for the enforcement programme. The compliance monitoring programme is designed to achieve the following objectives enhancing the credibility of environmental requirements, safeguarding consumer goods and services provided by a healthy ecosystem, protecting public health and safety, lowering impacts and risks to the quality of water resources, demonstrating the DWS' commitment to compliance by building a credible presence, boosting investor confidence by reducing business risks, encouraging innovation, and continuing to increase competitiveness (DWS, 2021). These goals are the critical drivers that enhance the directorate’s essential function: compliance monitoring audits, inspections, and objectives.

Further to that, with the support of the mandatory legislation, and water uses authorisation falling under the ambit of the NWA and other relevant environmental legislation seek to ascertain and monitor compliance; auditing of the water uses self-regulation, monitoring, and reporting systems; compliance through the project life cycle; promote compliance through awareness; and to implantation of action plans, follow-ups to ensure findings are implemented or through referral to Enforcement (DWS, 2021). All audit or inspection findings are provided in the form of an inspection report or an Audit report which concludes and details the status of compliance/non-compliance (DWS, 2021). These objectives are implemented through various sub-directorates within the compliance monitoring directorate, such as Compliance Monitoring: government and institutions, industry, mining, and agriculture.

For this research report, the review is focused on the Green Drop Certification, Compliance Monitoring: Government and Institutions, and its role in regulating the wastewater treatment of municipal facilities. The goal of the literature is to outline the main challenges and pinpoint any knowledge gaps that contribute to the inefficiency of the Green Drop certification program and its effects on the nation's river system and indicators of water quality.

2.4.3. Green Drop Certification

The uniquely South African concept of Green Drop Certification, an incentive-based policy, aims to address the difficulties facing the nation's water industry (DWS, 2022a). The Green Drop initiative seeks to promote organizational behavioural change so that wastewater networks and treatment systems may continually improve and adopt optimal management practices. Performance is regarded as excellent and continuous improvement is acknowledged and rewarded (DWS, 2022a). This recognition comes as a Green Drop Certification, which is given to sewage systems that achieve a score of more than 90% when measured against the defined standards for wastewater management, and on the other hand, systems that obtain a score of less than 31% is deemed to be a system that is dysfunctional which require a suitable intervention (DWS, 2022a).

However, a critical challenge exists in the suitable intervention within DWA; for example, the Green Drop Programme, as the point of reference for regulation, has no options to report systems that obtain less than 31% score to Compliance Monitoring: Government and Institution for authorised systems and to enforcement for those that are unauthorised. Even the work-based systems used by these three divisions—for instance, the one for the Green Drop Program is the Integrated Regulatory Information System (IRS), for CM: Government and Institutions and other Compliance Monitoring sub-directorates are the National Compliance Information Management System

(NCIMS), and the enforcement division employs the Enforcement Case Management System (ECMS)—are not connected. Only a handover button between NCIMS and ECMS, but the user who hands over a case cannot even view the status progress on the facility that was handed over.

Further, no business process exists between Green Drop and Compliance Monitoring and Enforcement only a Standard Operating Procedure between CM and Enforcement. However, the SOP must link the systems between these divisions, which hinders an instant response to pollution and effective regulation.

2.4.4. Compliance Monitoring: Government

The development and implementation of regulatory policies, strategies, protocols, guidelines, and standard operating procedures for compliance monitoring for the facilities, such as Water Boards, public works, municipal wastewater treatment facilities, and the municipal landfill sector, is the responsibility of the Sub-Directorate: Government and Institutions (DWS, 2022/2023a). This is accomplished through cooperation, promotion, continuous upgrading, and supporting effective compliance monitoring of water users within the sector by offering training or referring issues to enforcement.

2.4.5. Enforcement Directorate

The Enforcement Directorates' purpose is to promote and enforce compliance with relevant legislation to water, to enable successful prosecution through investigations and joints operations, and further identify, develop, and implement suitable enforcement tools based on local and international current experience and best practices to support in reaching compliance; also share and document learned lessons together with case law on water issues to enable DWS to effective enforcement action against transgressors and develop skill and build the capacity of DWS institutions, its enforcement personnel and its stakeholders (DWS, 2022/2023b). The directorate further holds engagements with Legal Support within DWA and the National Prosecuting Authority (NPA) concerning the referred cases, provides advice and support on criminal and administrative litigation and takes on awareness initiatives with stakeholders such as the South African Police Services (SAPS), NPA and Judiciary (DWS, 2022/2023a).

2.5. Reflection on Water Resource Management support tools

Despite the fight to stop the pollution of water resources (rivers) by partially treated effluent from municipal WWTWs, these laws allow for the management and protection of water resources that have been in place for a while. Based on observation and experience legal framework provided in this research above, these legislations have needed help to achieve their set goals due to the lack of proper coordinated implementation of the legislative resources. Secondly, the failure to uphold the principles of cooperative governance and intergovernmental relations is due to section 41(h) of Chapter 3 of the Constitution, which addresses the interaction between the National and Local Governments, in this case, the Department of Water and Sanitation and Municipalities. Section 41(h)(ii) requires these two governments to support and assist one another. This has resulted in the struggle of the water and sanitation department in terms of the National Water Act and the related regulations to easily regulate, or successfully enforce and be able to take the municipality for prosecution where necessary, due to the requirement of the former mentioned section of the constitution.

In a report by OUTA, AG examined the Department's assistance to local governments through the Regional Bulk Infrastructure Grant (RBIG) and the Water Services Infrastructure Grant (WSIG) and found that, among other things, DWS lacks planning, project management capabilities, and engineering expertise (OUTA, 2017). Also, the DWS internal structures need to communicate or work together about fund distribution; infrastructure development does not consult with systems such as the compliance monitoring sub-directorate (government) and the Green Drop section, which are responsible for water resource regulation. This issue extends to the specialized units responsible for technical and regulatory functions and the database. For example, one of the critical challenges exists on the suitable intervention within DWA; for example, the Green Drop Programme, as the point of reference for regulation, has no options to report systems that obtain less than 31% score to Compliance Monitoring: Government and Institution for authorized systems and enforcement for those that are unauthorized.

This issue even exists in the work-based systems of these three divisions. For example, the one Green Drop Programme is Integrated Regulatory Information System (IRS), for CM: Government and Institutions and other Compliance Monitoring sub-directorate is the National Compliance Information Management System (NCIMS), and the enforcement division uses Enforcement Case Management System (ECMS) are not linked. Only a handover button between NCIMS and ECMS, but the user who hands over a case cannot even view the status progress on the facility that was handed over.

Considering all of the problems that DWA has, including the constraints imposed by law, the internal organizational structure of DWS, and the database management systems, to name a few, has harmed the critical objectives of the Green Drop Initiative. This is a severe hurdle as the programme seeks to encourage behaviour change in institutions (individually or as cohorts) to continuously enable improvement and practice management adoption at wastewater networks and treatment systems.

Hence, the behaviour of some of the municipalities is somehow concerning as far as wastewater purification is concerned. When some WWTWs discharge partially or untreated effluent to the waterways, as in this case, the river ecology, it puts tremendous pressure on the receiving environment and makes it more challenging to protect the nation's rivers. When some effluent fails to meet the specified water use authorizations' parameters for general standards or limits for water quality, as applicable.

2.6. General Water Quality Standards

General Water Quality Standards for operations in terms of Section 21(f) under the General Authorisation (GA) in terms of Section 39 of the NWA, 1998 (Act No. 36 Of 1998). These activities entail discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall, or other conduit controlled by another person authorized to undertake the purification, treatment, or disposal of waste or water containing waste, subject to the approval of the person controlling the canal, sea outfall or other conduits. To carry out this activit,y as mentioned above a water user, should apply for water use authorization from the Department of Water and Sanitation.

Therefore, depending on the quality and quantity related to activities under section 21(f) of the act, a water user can either be issued an authorisation under the ambit of the GA or a WUL, if the activities exceed the requirements of the GA. An authorisation issued as a WUL will be provided with specific water quantity and quality limits depending on the characteristics of water user activities. It should be further mentioned if where the water user activity to take place is located in the vicinity of a catchment or rivers that are listed. Therefore, the water user will be issued with a WUL straight whether the water user activities fall under GA ambit will be obligated to apply for WUL that subject to stringent conditions and unique (Table 2.1) quality and quantity limits.

Table 2.1: Wastewater limit values applicable to the discharge of wastewater into a water resource (DWS, 2013)

SUBSTANCE/PARAMETER	GENERAL LIMITS	SPECIAL LIMITS
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	
Suspended Solids (mg/l)	25	10
Electrical Conductivity (mS/m) above background	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
Orthophosphate 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
SUBSTANCE/PARAMETER	**GENERAL LIMITS**	**SPECIAL LIMITS**
Dissolved arsenic (mg/l)	0.02	0.01
Dissolved cadmium (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 compound (mg/l)	0.005	0.001
Dissolved Selenium (mg/l)	0.02	0.02
Dissolved Zinc (mg/l)	0.1	0.4
Boron (mg/l)	1	0.5

General Water Quality Standards for activities in terms of Section 21(f) under the General Authorisations in terms of section 39 of the National Water Act, 1998 (Act No. 36 Of 1998)

It should be noted that the water quality standards above are confirmed general standards for wastewater treatment facilities under the General Authority (GA) (DWS, 2013). The facilities within the GA ambit discharge up to 2000 cubic meters of wastewater on any given day into a water system that is not a listed water resource in Table 2.3 (DWS, 2013). Secondly, discharge up to 2 000 cubic meters of wastewater on any given day into a listed water resource set out in Table 2.3 of the GA or Table 2.1 of this report (DWS, 2013). However, those WWTW facilities discharge up to 2 000 cubic meters of wastewater on any given day into a water resource are required to apply for Water Use Authorization in terms of chapter 4 of the National Water Act No. 36 1998. The water user will be issued Water Use License (WUL) in terms of Section 40 of the National Water Act, 1998 (Act No. 36 of 1998) authorises the use of water for sewage treatment-related activities such as discharging of treated effluent from a WWTW, in terms of section 21(f) of the Act, into a water resource. These facilities will be given specific water quality standards only applicable to those facilities, drawn according to each facility's quality and environmental characteristics.

2.7. Water Resources Protection Challenges

Despite having all the contributing factors and systems in place to deal with the continuous pollution of rivers by WWTWs, the country continues to deal with the strain of polluted rivers. The rivers are polluted by the discharge of effluent that is not of the required standards (table 2.1) from municipal wastewater treatment facilities. Edokpayi and others pointed out that the critical freshwater point sources of pollution are raw and or poor and insufficient treatment effluent discharged to it, and this remains a considerable challenge for the republic (Edokpayi et al., 2017; Ntombela et al., 2016). This challenge is mainly due to improper maintenance of wastewater treatment facilities, sewer line infrastructure and exacerbating non-compliance incidents with legislative provisions, policies, norms, and water resource management standards intended to guard water resources. (Mema, 2010 and Ntombela et al., 2016). Le Roux and others in 2012 described Olifants River as among the most ecologically contaminated in Southern Africa. Some contamination constituencies detected were faecal indicator bacteria and harmful micro-organisms (le Roux et al., 2012). Based on this finding from this study, one can rest assured that the pollutants originated from a wastewater treatment facility that causes strain to receiving waters.

These issues of non-performing wastewater treatment works have been highlighted over the year. To curb this issue alongside the DWS, the then DWAF took an institutionalised initiative by establishing incentive-based regulation programs in 2008 (DWS-GD, 2022). These programs are known as the Blue Drop and Green Drop certification initiatives, and they were intended to act as an incentive for established catalytic motivation, change, and guidance for wastewater management services in the water sector (Burges, 2016). The Green Drop program's specific purpose was to change how wastewater management, operation, and regulation are conducted. In a nutshell, it stands to promote incentive-based regulation to establish excellence as a wastewater service yardstick (Burges, 2016). The progressive trend of this program was seen in the WWTW's performance after each assessment from 2009 to 2013, as shown in the comparative analysis below.

Table 2.2: Green Drop Comparison Analysis from 2009 to 2013

GREEN DROP COMPARATIVE ANALYSIS				
Performance Category	***2009***	***2010/11***	***2012/13***	***Performance Trend***
Number of municipalities assessed	98	156 (100%)	152 (100%)	→
Average Green Drop score ≥ 50%	37%	45%	46%	↑
Number of Green Drop score ≥ 50%	216 (49%)	361 (44%)	409 (50.4%)	↑
Number of Green Drop score < 50%	228 (51%)	460 (56%)	409 (49.6%)	↑
Number of Green Drop awards	33	40	60	↑
Average Site Inspection Score	N/A	51.4%	57.0%	↑
NATIONAL GREEN DROP SCORE	N/A	71%	73.8%	↑

N/A = Not Applied, ↑ = Improvement, ↓ = digress, → = no change

However, even though the programme’s aims and objectives are clear, it has faced some challenges, such as the implementation of the programme by municipalities. This has been exacerbated by a few challenges emanating from the municipalities, such as DWS’s complex relationship with the municipalities, Limited resources that consider increasing popularity and decision-making for wastewater treatment, a paucity of proactive planning, a lack of capability for the creation of efficient remedial action plans or wastewater risk abatement approaches, issues with the administrative process, vandalism, theft and wastewater treatment mismanagement of infrastructure and the lack of transparency (Ntombela et al., 2016 and Mema, 2010). Viewing the performance progress in the comparative analysis in the table above, the non-conduction of green drop assessment and non-release contributed to the relapse of the performance in municipalities. Internal challenges within DWS , such as failing to publish the Green and Blue Drop Reports from back in 2013 and the non-assessment of water facilities, have substantially contributed negatively to operations and management, risk mitigation, and remedial actions and treatment plans (SAWIC, 2018).

2.8. DWS internal organisational challenge

The Department of Water and Sanitation (DWS) mandate, as set out in the National Water Act, 1998 (Act No. 36 of 1998) (NWA) and the Water Services Act, 1997 (Act No. 108 of 1997) (WSA), is to ensure that the water resources of South Africa are managed, used, controlled, protected conserved, and developed by regulating and supporting the delivery of adequate water supply and sanitation (DWAF, 1998). To carry out this mandate, the Department has established three internal components Administration, Water Resource Management, and Water Services Management, which are divided into sub-programmes as shown in Figure 2.1 below.

PROGRAMME 1 ADMINISTRATION	PROGRAMME 2 WATER RESOURCE MANAGEMENT	PROGRAMME 3 WATER SERVICE MANAGEMENT
Minister	Water Resource Management Support	Water Services Management Support
Departmental Management	Integrated Water Resource Planning	Water Services and Local Management
Corporate Support Service	Water Ecosystems Management	Regional Bulk Infrastructure Grant
Financial Management	Water Resources Information and Management	Water Services Infrastructure Grant
Provincial and International Coordination	Water Resources Infrastructure Management	Water Service Policy & Strategy
Office Accommodation	Water Resources Policy and Strategy	Water Services Institutional Oversight
	Water Resources Regulation	Water Services Regulation
	Water Resources Institutional Oversight	

Figure 2.1: Department of Water and Sanitation Organisational Framework (DWS, 2022a)

The administration component: provides the ministry and the department with strategic leadership, management, and support services through various initiatives, including financial management, shared corporate support services, and the coordination of water resources across nearby nations (DWS, 2022a).

Component for the Management of Water Resources: This component is charged with the technical responsibility of ensuring that water resources are conserved, developed, managed, and controlled sustainably for the benefit of all people and the environment. It creates a knowledge foundation that will aid in proper planning and well-informed decision-making. Additionally, it provides for designing efficient policies and processes and supervising all institutions involved in water resource management (DWS, 2022a).

Component of water services management: This component supports water services authority by addressing the provision of water and sanitation services along the whole value chain of water and sanitation. Ensure the integration of wholesale and retail to improve the sector's coherence, recognize economies of scale, and promote water efficiency. This component also plays a significant part in formulating efficient policies, procedures, strategies, plans, guidelines, and the rules and oversight for all institutional water service management (DWS, 2022a).

To safeguard the water resource and provide high-quality water to all communities, these elements are what drive the department's agenda. The fulfillment of all South Africans' constitutional rights, economic progress, and human health and well-being depends on this. Additionally, among other things, these internal structures are in charge of creating successful strategies and plans (DWS, 2022a).

This research focuses on the Water Resources Management Component Water, where its mandate is implemented under the Water Use, Compliance Monitoring, and Enforcement Directorate. This focus is further narrowed to investigate directorates and sub-directorates responsible for protecting water resources through regulating Water Service Authority facilities (municipalities) for both portable and wastewater. These directorates and sub-directorates are the Water Service Regulation directorates (with Blue and Green Drop sub-directorates), incentive-based regulation sectors. Secondly, the Compliance Monitoring Directorate which several sub-directorates such as Mining, Government and Institutions, Agriculture and Forestry sectors, Industrial sector, and dam safety regulations. All these are designed to ensure and provide assurance of compliance to water use regulations through compliance monitoring, and the enforcement directorate. Within these directorates, there are sub-directorates explicitly looking at the code of municipal wastewater facilities only Green Drop sub-directorate and Compliance Monitoring: Government and Institutions and enforcement directorate among its functions are to enforce non-compliances on these facilities.

Therefore, this research Green Drop sub-directorate and Compliance Monitoring: Government and Institutions and Enforcement is the focus point. One would anticipate active water service management and water resource management given the number of components now attempting to manage water services and resources through incentives, assistance, regulation, and enforcement in the municipality. However, considering the current business setup observed in these directorates and their sub-directorates thereof, there are no linked standard operating procedures between the Green Drop sub-directorate and Compliance Monitoring: Government and Institutions sub-directorate. This implies that no operational document relates the functions between these divisions, and this has a negative working relationship because Green Drop Sub-directorate as the incentive support to water service authorities (municipalities) its operations are not linked to the compliance monitoring government and institution sub-directorate. For example, suppose during assessments, one facility is found to be transgressing. In that case, a notice is repeatedly sent via the work-base system known as the Integrated Regulatory Information System (IRIS) without the matter being directed to the CME divisions.

Additionally, the Compliance Monitoring Directorate and the Enforcement Directorate are linked through an operating standard procedure and their systems, however, the interaction between these directorates is one-sided because standard operating procedures provide a business process that requires non-complying facilities to be handed over to enforcement for further investigation that can lead to prosecution against the transgressor. The downfall is that once compliance monitoring sub-directorate personnel hand over the facility to enforcement that is the last time they know about that facility's compliance progress. Understandably, once the matter is handed over to enforcement, it becomes confidential to avoid interference with the investigation and the case. This situation could be resolved by allowing the compliance monitoring officer to view the status and progress of the investigation and the case without being able to view the contents. More interactions between these two divisions must be made, which impedes effective water resource management and protection. Different divisions within DWS, as highlighted above, carry out this resource management and protection with the same objective but work in parallel.

The parallel system within the department results in a lack of interaction among these sub-directorates. It plays a significant negative role that must still be recognized or seen as a problem. Further to these, in respect of the challenges highlighted above, even the work-based systems for these directorates and sub-directories, such as the Integrated Regulatory Information System (IRIS), the National Compliance Information Management System (NCIMS), and the Enforcement Case Management System (ECMS), are not linked. Only NCIMS is linked to ECMS via a handover button; otherwise, compliance monitoring officers have no access to ECMS, and feedback is not provided via the system or in any other form. A compliance monitoring officer can only receive input through a request to the enforcement office handling the case. If the facilities have been turned over to enforcement for investigation and the enforcement directorate fails to notify the compliance monitoring directorate of the progress of the investigation, either through NCIMS or any other means of communication, neither after enforcement action has been taken, be it notice or a directive by enforcement, nor if the water users have responded to implement the directive's requirements.

Additionally, Even data-based systems, like the Water Management System (WMS) for data on water quality and the Electronic Water Use Licence (WUL) Application and Authorization System (e-WULAAS) for the application, processing, and issuance of water use authorizations, are not connected to the work-based systems mentioned above, which creates additional challenges for the country's efforts to manage and protect its water resources effectively. Both the work-based and data-based systems have different functions, keeping information that seeks to achieve the objective of resource management and protection, and their functions are as follows:

2.8.1. The Integrated Regulatory Information System (IRIS)

The System was first created to assist in the interaction between the regulation and management of water supply systems while informing key stakeholders about compliance trends of all registered supply systems. The system's goal is to aid DWS Water Services Regulation in more effectively controlling the water services sector in the country. The challenge with this system is not linked to any of the systems mentioned above and hinders the prompt and instant response issue of non-compliance. An enforcement or compliance officer would only acquire access rights through a specific procedure. If more than the publicly available data is needed for a compliance or enforcement investigation at a particular time, it comes with limitations, even for DWS employees who are not system users and are not offered rights to access it.

2.8.2. National Compliance Information Management System (NCIMS)

NCIMS is a DWS tool that helps the department with compliance monitoring operations and actions. Coordination and monitoring of compliance with legal (primary and secondary) standards are the goals of these activities/actions. Moreover, this refers to the terms and guidelines for water use entitlements that apply to all industries, including resource-directed policies, dam safety standards, and solid waste restrictions. The challenge is instant access to IRIS, ECMS, WMS, and e-WULAAS information.

2.8.3. Enforcement Case Management System (ECMS)

ECMS is a centralized system that enables the electronic management and processing of case-related information. It is utilised as an electronic solution for the management of non-compliance cases reported to ensure necessary rectification measures are instituted against suspected offenders from the moment, they are reported to the time of the resolution phase. The system aims to improve operational efficiency, compliance with administrative enforcement, and civil and criminal requirements. Similarly, the challenge is instant access to IRIS, NCIMS, WMS, and e-WULAAS information.

2.8.4. Electronic Water Use Licence Application and Authorisation System (e-WULAAS)

A double goal drives e-WULAAS. One is to give customers of the Department of Water and Sanitation (DWS) access to an online application portal to register and submit their water-use authorization requests. Two: The system will offer an internal web-based interface for the authorisation personnel to monitor, coordinate, track, and complete the authorisation processes of registered water uses, culminating in issuing a water use license. The challenge is instant access to water use authorisation, which can only be obtained upon request from the licensing division.

2.8.5. Water Management System (WMS) and challenges of the above-mentioned databases

The biggest downfall with these systems is that they need to be integrated in the sense that all related systems users can only view and download information if one is registered for access. For example, the Departmental official who deals with compliance monitoring needs access to WMS, or e-WULAAS through NCIMS. This suggests that someone who evaluates compliance for authorized facilities has no access to water use authorization or water quality information other than what they request via email to the system managers. As opposed to linking these systems with viewing and downloading rights, for example, NCIMS to e-WULAAS, WMS, and IRIS, NCIMS linked to ECMS with limited access with only a handover button and viewing the investigation status. On the other hand, ECMS users should be able to view and download reports from IRIS and MCIMS as the form bases of analysis for enforcement. As things stand these systems work parallel and have no link nothing

In addition to the data and work-based systems for managing water resources, the Department of Water and Sanitation needs help regulating wastewater treatment facilities by internal DWS institutions. The integration of the South African organization managing and regulating wastewater treatment needs to be addressed. For instance, the divisions responsible for water quality, green drops, compliance monitoring, and enforcement might visit the same water service authority within a week and request the same data while keeping one another informed. These difficulties make it difficult to effectively regulate water users to preserve water resources from effluent discharge from municipal wastewater treatment plants, continually degrading the quality of receiving rivers.

2.9. Effluent Discharge Impact on the Rivers

The wastewater treatment works discharge of partially or untreated effluent has a significant health effect that is detrimental to the aquatic ecosystem (Pereao et al., 2021; Edokpayi et al., 2017; and Wakelin et al., 2008). The receiving water bodies' waterways may receive significant amounts of nutrients and organic debris from the WWTWs discharge outlets (Wakelin et al., 2008). While an increase in the organic matter could change the energy dynamics in the watercourse, cause biotic structural community disruption, and impair biotic community functioning, an increase in nutrients could cause temporary oxygen deficiencies and eutrophication (Wakelin et al., 2008). Further to that, the discharge of effluent could also carry and deposit grit and sand into aquatic systems, affecting the sedimentation’s physical characteristics (Wakelin et al., 2008). The effluent discharge activity could disturb the natural flow regime, especially during periods of low natural flow when it enters waterways (Wakelin et al., 2008). This may result in the degradation of the ecological system extensively, for example, a deterioration in water quality that will cause a loss of species, a change in the distribution of aquatic biota, and reduced availability of water suitable for use (Edokpayi et al., 2017), if not adequately monitored (Pereao et al., 2021).

Furthermore, this has resulted in a compromised water resource (a river) that could be more sustainable for balancing a country's water demand. (Edokpayi et al. 2017). Poor river water quality caused by inadequately or improperly treated effluent discharge extends to health issues, particularly in underprivileged communities, and is widespread in most developing countries (Muisa-Zikali et al., 2015 and Mema, 2010). There have been numerous reports of wastewater discharge WWTW consequences in various regions of the nation.

The Pienaars River, Tolwane, Hennops, and Apies Rivers that drain to Roodeplaat Dam and are close to the City of Tshwane were all polluted in 2019, according to a report by the Gauteng Provincial Office of the South African Human Rights Commission (SAHRC, or "the Commission") (SAHRC, 2021). In December 2018 in the City of Tshwane Metropolitan Municipality, it was reported by DWS that it had been shuttered due to malfunctioning wastewater treatment works that date back to 2010. A few of those that have been identified are Klipgat, Rooiwal, Baviaanspoort, and Sunderland Ridge Wastewater Treatment Works (SAHRC, 2021). As a result, the commission has received complaints about WWTWs, particularly Baviaanspoort, Rooivaal, and Temba, since 2018 (SAHRC, 2021).

The members of the community of Hammanskraal complained that they had been subjected to malodorous dirty water, which was alleged to be due to malfunctioning Rooivaal and Temba WWTWs. As a result, the SAHRC investigated the form of interviews by visiting the local schools, clinics, and hospitals, and further conducted several site inspections in the Rooivaal and Temba WWTWs (SAHRC, 2021). Following the completion of this task by the commission, it was determined that these WTW were indeed the source of nuisance in that community. The commission recommended that urgent intervention was needed in Rooivaal to stop the overflow of untreated wastewater, and Temba was being renovated at the time (SAHRC, 2021).

Similar to the above case, the Baviaanspoort WWTW was not working correctly. As a result, raw sewage was being discharged into the Pienaars River, which ultimately flowed into the Roodeplaat Dam. This information was provided to the Commission by the complainants. Water quality issues in the Pienaars River have harmed aquatic ecological life. These investigations were conducted in the Baviaanspoort, Rooivaal, and Temba WWTWs over six months, from June to December 2018. (SAHRC, 2021). Additionally, faecal indicator bacteria that could have acted as a cover for pathogens and other microbes were found in high concentrations in the Apies River sediments, which Abia and colleagues discovered in 2015. Hence, the communities who use the river's untreated water for recreational and other uses could face health hazards due to the discharge of such viruses into a water body caused by human activities or other unforeseeable events like floods (Abia et al., 2015).

In 2010, Mema researched the effects of inadequately maintained wastewater and sewage treatment facilities—a lesson from South Africa. It was discovered that a cause of concern in South Africa from the perspective of sewage discharge emanates from local municipalities serving low-income communities (Mema, 2010). These plants were not meeting the minimum legal discharge standards (Mema, 2010). The investigation found that more than 80% of effluent discharges in the Eastern Cape did not adhere to the necessary effluent regulations, and it issued a warning that if the situation persisted, health and hygienic issues would have arisen (Mema, 2010).

However, at the time of this investigation, some parts of the Eastern Cape (EC) and KwaZulu Natal (KZN) in certain municipalities were already facing health issues associated with sewage spills. For example, in 2008 in the EC, in areas such as uKhahlamba District Municipality, sewage spills were reported, which led to a wastewater surge that caused sickness and death in the local communities (Mema, 2010). Further, a similar situation was reported in urban areas, such as sewage discharge into Durban Harbor and wastewater pollution of water resources in places such as the Western Cape and Gauteng (Mema, 2010). The results of this study show that, even though low-income communities were more severely impacted than urban municipalities (Mema, 2010), several factors, such as ineffective operation and management, inadequate treatment procedures, malfunctions, plant design issues, and insufficient waterborne sanitation systems, were responsible for the discharge of partially or untreated effluent into the water resource (Mema, 2010).

In the Eastern Cape Province in 2019, Adams and other researchers found that wastewater treatment facilities in the Swartkops watershed were a significant source of nutrients that fueled the spread of water hyacinth and aquatic invasive plants in the rivers between Perseverance and Uitenhage (Adams et al., 2019). Concerns about water quality were also raised because nutrients that aided the rapid growth of algae in river systems unintentionally disturbed the equilibrium of aquatic organisms. In addition, the Swartkops River is the leading supplier of phosphorus for the estuary due to the upstream WWTWs, which are different from the Motherwell Markman canals, which give the majority of nitrogen to the estuary. Three of these upstream Kelvin Jones, Despatch, and KwaNobuhle WWTWs were found to be operating over design capacity at 75 ML/day, 77 ML/day, and 79 ML/day, respectively (Adams et al., 2019).

Furthermore, Dabrowski and de Klerk conducted an impact assessment study on water quality in 2013 at the Olifants River. The results of this study, extremely high amounts of orthophosphate and nitrogen, which are often linked to sewage inputs, were found within a short distance downstream from the Riverview sewage works (Site 5 OLF) in Witbank (Dabrowski and de Klerk, 2013). The average ammonia concentration was 6.8 mg/l, exceeding the permitted limit of 0.1 mg/l, while the orthophosphate average instream concentration likewise exceeded the South African effluent requirement of 1 mg/l.

Then it was concluded that Riverview WWTW operations were not up to the accepted standard because they released high concentrations of unacceptable nutrients into the Olifants River (Dabrowski and de Klerk, 2013). In 2014, a newspaper article by Witbank News on a campaign titled "Wastewater treatment plants are the culprits" confirmed that major contributors to issues of water quality at the Olifants River are wastewater treatment plants. (Riverview WWTW used as a case study; Witbank News, 2014)

Further, Dabrowski and de Klerk observed in 2013 that this problem has persisted in the upper olifant catchment, as several WWTWs scored very poorly in the 2011 Green Drop assessment. Additionally, it was discovered that the observed high concentration in the Olifants River provided more evidence indicating that the upper Olifants' quality is compromised because of WWTW's poor standards (Dabrowski and de Klerk, 2013). Again, in 2020, the USAID group discovered that eutrophication indicates an abnormality across the upper Olifants catchment, and the cause is phosphate released to the Olifants River due to WWTW's effluent discharges that are non-compliant with set limits. (USAID, 2020). The issue related to the compliance challenges of the WWTWs has resurfaced and contributed to a decline in the performance assessment of the WWTWs as they appear on the 2022 Green Drop Report.

Additionally, a few river catchments that receive effluent discharges from municipal wastewater treatment works have been visited during this research. These systems were the Sand River, Kariega River, and Kowie River.

2.9.1. Sands River Catchment

The observations made for the Sand River Catchment were in the vicinity of the discharge point at Polokwane WWTW, Polokwane City, in Limpopo Province. The data shows that the facility needs help to meet the required limits of effluent to be discharged to Sand River. The parameters are E. coli, EC, COD, NH3, PO4, and SS, which have been a problem for the facility. The variable was observed for two (2) months (June and July 2022). looking at the microbial parameter E. coli obtained from IRIS and comparing it to the Water Use License (WUL) issued to Polokwane WWTW with a zero-limit count per 100 ml. The facility cannot attain the zero limit downstream of the location where the final effluent is discharged into Sand River since the average upstream E. coli concentration is 45.6 counts per 100 ml. The Sand River downstream of the Polokwane WWTW discharge site has an average count of 179,375 counts per 100 ml despite the limit issue. The facility's Sand River discharge limit is higher than this one.

2.10. Water Quality Indicators

Water quality is defined as the physical, chemical, biological, and aesthetic properties of water that determine its suitability for a variety of recognized uses and the preservation of the integrity and health of the aquatic ecosystems therein, according to the South African Water Quality Guideline, Volume 7, published in 2006. (DWAF, 1996a). The dissolved or suspended components in water affect and manage these qualities. the inorganic constituent's aluminium, ammonia, arsenic, cadmium, chlorine, chromium (III) and chromium (VI), copper, cyanide, fluoride, iron, lead, manganese, mercury, selenium, and zinc, as well as the organic constituents atrazine, endosulfan, and phenol, as well as system variables (physical parameters) such as dissolved oxygen, pH, temperature, and total suspended solids, are listed (DWAF, 1996a).

2.10.1. Physical parameters indicators

Generally, physical parameter indicators give the physical characteristics of water, in terms of temperature, pH, and electrical conductivity.

2.10.1.1. Temperature (T in ºC)

Temperature is critical in aquatic life because it determines the types of organisms and their distributions that can survive (Dallas and Ross-Gillespie, 2015). Variations in atmospheric conditions cause temperature changes in water systems, which can also apply to humans (Li et al., 2017; and DWAF, 1996a). The average daily background water temperature at a particular site shouldn't be allowed to vary from the water temperature (Dallas, 2009). It has a significant impact on a number of the chemical and physical properties of water, including the solubility of oxygen and other gases, chemical rates and toxicity, microbiological activity, and the presence or absence of pathogens (Dallas, 2009). Since river water is often warmer than wastewater treatment effluent is discharged into the water (Wilson & Worrall, 2021).

As a result, discharging effluent outside of its temperature range may negatively impact aquatic ecosystems. Even if the temperature remains outside the scope to which aquatic species can adapt for an extended period, it may affect reproduction, feeding capacity, patterns, growth, and metabolism (Whitehead et al., 2009). In addition, greater temperatures may limit the solubility of dissolved oxygen in water, lowering its concentration and availability to aquatic species (Dallas, 2009). Hamdhani and others highlighted that elevated temperatures downstream of effluent discharges could cause several ecological impacts, such as increased production rates and biomass. Again, warmer water combined with high nutrient content in the area that receives effluent discharges could result in eutrophication, and a few aquatic species adapt to a specific range of temperature; if that range is increased, it may exclude taxa that are sensitive in an effluent discharge area (Hamdhani et al., 2020).

2.10.1.2. pH (pH-units)

pH is described as the negative logarithm of the hydrogen content in a solution, which hence determines whether the solution is acidic or alkaline (DWAF, 1996a, and WHO, 2007), and the measure is determined using the following equation:

$$pH = -\log [H^+]$$

$[H^+]$ denotes hydrogen ion concentration.

Concentration is measured in a solution after it is determined that the pH is less than 7; it has an acidic concentration, and if it is greater than 7, it has an alkaline concentration (DWAF, 1996a).

As a result, the direct discharge of acidic effluent into water containing bicarbonate alkalinity, among other things, may result in the free formation of carbon dioxide. Then, free CO in alkaline water can be liberated and be toxic to fish species (DWAF, 1996a).

2.10.1.3. *Electrical conductivity (EC in mS/cm)*

EC measures how well water can carry an electrical current, according to specific sources (DWAF, 1996a). The presence of ions such as bicarbonate, carbonate, chloride, sulfate, nitrate, sodium, potassium, calcium, and magnesium results in this ability. General limits for WWTWs discharge are shown in Table 2.1 above. Numerous dissolved organic compounds in water do not dissociate into ions; subsequently, they do not affect the EC (DWAF, 1996a) (DWAF, 1996a). Nonetheless, a general limit of 70 mS/m above input up to 150 mS/m is accepted for discharge into a water resource. (see Table 2.1 above).

2.10.2. ***Chemical parameters indicators***

The chemical processes and features of water are represented and caused by the chemical indicators found in it. These parameters are chosen based on the purpose and scope of the water quality monitoring, but for this report, the following have been analysed:

2.10.2.1. *Sulphate*

It is a substance that occurs naturally, contains elements such as sulphur and oxygen, and exists in various salts found in minerals. Some salts are formed with sulfate and various elements, including magnesium, barium, potassium, calcium, and sodium. The high sulfate concentrations in water might result in health issues such as diarrhea (DWAF, 2012).

2.10.2.2. *Nitrate as NO_3*

Nitrate is created when ammonia or nitrite are oxidized, as well as the nitrogen oxyanions nitrate (NO3-) and nitrite (NO2-), found in the +V and +III oxidation. These substances, like nitrates and nitrites, coexist in the environment and are easily converted into one another. In oxidation circumstances, nitrite is transformed into nitrite, which is far more prevalent than nitrite in aquatic environments and is primarily the stable positive oxidation of nitrogen. The health risks of nitrate in drinking water stem from the ease with which it can be converted to nitrite in the digestive tract due to the loss of microorganisms. (DWAF, 2012).

2.10.2.3. *Orthophosphate (as P)*

Orthophosphate as phosphate, as an inorganic constituent, is a phosphoric acid salt, and on the other hand, as an organic constituent, it is a phosphoric acid ester. The amounts of phosphates and nitrates in aquatic habitats may cause eutrophication (Shabalala et al., 2013).

2.10.2.4. Ammonia

At room temperature and pressure, ammonia has an unpleasant odour in its unionized form. It is produced naturally due to the biological breakdown of nitrogenous material and is essential to the nitrogen cycle. It can exist as the free, unionized form (NH3) or as the ammonium ion (NH4+), an ionized form. These are reduced forms of inorganic nitrogen mainly produced during organic matter's aerobic and anaerobic breakdown.

The unionized form of ammonia (NH3) correlates directly with its concentration, but the ammonium ion (NH4+) has very little to no harm to aquatic life. Ammonium ions do, however, contribute to eutrophication. (DWAF, 1996a).

2.10.2.5. Turbidity

Turbidity occurs when dissolved and suspended particles in water scatter, making them appear murky or cloudy. This particulate could be clay or silt sediments, coloured soluble organic matter, fine inorganic or organic matter, algae, or other microscopic organisms (MPCA, 2008). The visual value of streams may be significantly diminished by a high dominant level of turbidity in the water, which can also impact recreation and tourism. It can also disrupt aquatic life by decreasing spawning beds, limiting the food supply, and compromising the functioning of the gill (MPCA, 2008).

2.10.2.6. Total Alkalinity as $CaCO_3$

Total alkalinity is the name given to the water's quantitative capacity to neutralize acid and provides the total carbonate and bicarbonate concentrations. The measurement of alkalinity is significant for streams' ability to neutralize acidic pollution from rain or wastewater (DWAF, 2012).

2.10.2.7. Iron (Fe)

Iron plays a vital role in aquatic environments because it is closely attached to various biotic and abiotic phenomena (Heikkinen et al., 2022). However, Fe loading harms aquatic organisms' food resources, survival, growth, and reproduction due to the toxic compound action of Fe. The toxic activity of the Fe compound may reduce species diversity, benthic invertebrates, fish, and periphyton abundance (Heikkinen et al., 2022).

2.10.2.8. Manganese

It is an essential micronutrient for plants and animals, a valuable part of nitrate assimilation, and a significant catalyst for several enzyme systems in plants and animals and bacteria. Insufficient amounts of manganese may hinder the expected growth of leaves and the productivity of photosynthesis, or it may result in chlorosis. (DWAF, 1996a).

Conversely, manganese deficiency results in skeletal abnormalities and diminished reproductive capacity in animals. Once more, toxic doses of manganese can cause disruptions in several metal pathways, most notably the disruption of the central nervous system through the inhabitation of dopamine production. (DWAF, 1996a)..

2.10.2.9. Sodium

An example of an alkali metal is sodium, which when combined with water produces the highly soluble, positively charged Na+ ions. Its concentration, which ranges from 100 to 200 mg/l, has no health effects, even though exceeding limits has a high salt content (DWAF, 2012).

2.10.2.10. Aluminium

Although aluminosilicate minerals are too insoluble to participate in bio-geochemical interactions easily, they are the main form in which aluminium is found. It is a powerful metal that hydrolyses yet is insoluble in neutral pH levels. If it were distributed as complexing ligands or in acidic (pH 6.0) or alkaline (pH > 8.0) environments, its concentration would rise, which might not be suitable for aquatic life. (DWAF, 1996a).

2.10.2.11. Chemical oxygen demand (COD)

It is defined as the amount of dissolved oxygen in the water that must be prestor to oxidize chemical and organic constituents. It is used to gauge the amount of oxygen in receiving river systems as a short-term wastewater effluents impact gauging parameter (Chemical Oxygen Demand (COD) - Water Quality Parameter | Hach, n.d.).It believes that when treated effluent is discharged into receiving water bodies, it may introduce pollution in the form of organic content into these bodies. Therefore, elevated COD levels in wastewater indicate the presence of organic concentrations that can deplete oxygen that is dissolved in water. As a result, the environment suffers from pollution and regulatory issues (Chemical Oxygen Demand (COD) - Water Quality Parameter | Hach, 2022).

2.10.3. Microbiological parameter indicators

Microbial organisms are commonly found as particulate matter associations or clumps (Bartram and Ballance, 1996). Microorganisms are common microbiological indicators in freshwater, including viruses, bacteria, protozoa, parasites, and helminths (Hageskal et al., 2009).

2.10.3.1. Escherichia coli (E. coli)

Escherichia coli is found in the feaces of warm-blooded animals and people. Because E. coli commonly occurs with organisms, they are not bacterial pathogens, and their presence indicates water hygiene quality in general (WHO, 2008). Hence, it is a water quality requirement that it must not have these bacteria (E. coli) in water used for consumption (DWAF, 1996a).

2.10.3.2. Total coliforms

The 2006 DWAF water quality guideline for aquatic ecosystems describes total coliform as all colonies producing bacteria (DWAF, 1996c). The totally coliform (TC) is a group of bacteria comprising soil and faeces, which come from non-faecal sources (EPA, 2001). Most TC bacteria are regulated for residential and recreational uses, and South African regulations state that safe drinking requires a faecal coliform level of no more than 5 counts per 100 mg/l (DWAF, 1996c).

2.11. Effects of Microbial Constituencies on receiving water bodies

Pathogenic bacteria are a frequent surface water component that enters a water resource with untreated, partially treated, or treated effluent (Augustyn, 2016). Minimal levels of the pathogenic microorganisms on the receiving water bodies are present and do not endanger human life or health. Still, when they are present in large quantities, they can be pathogen factors and cause discomfort (Augustyn, 2016Again, a variety of factors, such as the size of the stream, the water level, the season, the contributing tributaries, the area where the river flows, the degree of eutrophication of the river system, and its capacity for self-cleansing, all affect the number of pathogenic bacteria in a river system (Augustyn, 2016). Moreover, a high E. coli level in effluent released into a water body could be harmful. Even though water quality experts assert that it is a trustworthy indicator of faecal contamination and pathogens in a river system (von Sperling, 2007).

CHAPTER 3: METHODOLOGY

3.1. Study Area

The study area is in Polokwane, from Sand River. The geographical location coordinates for the sample area are S 25º 50' 36" and E 29º 15' 57. " Sand River ascends from the mountains of the Northern Drakensberg and flows easterly towards the direction of Kruger National Park until it meets with the Sabie River near Skukuza, Mpumalanga. (Seanego, 2013). Its largest contributing tributary is the Mutlumuvi River, which also rises in the Northern Drakensberg Mountains and travels eastward until it meets the Thulamahaxi Region's Sand River. (Seanego, 2013). However, both the Mutlumuvi and Sand Rivers in the upper catchment have several small tributaries feeding them (Figure 3.1) (Seanego, 2013). The Sand River sub-catchment near Polokwane City, near the discharge point of Polokwane WWTW, was assessed.

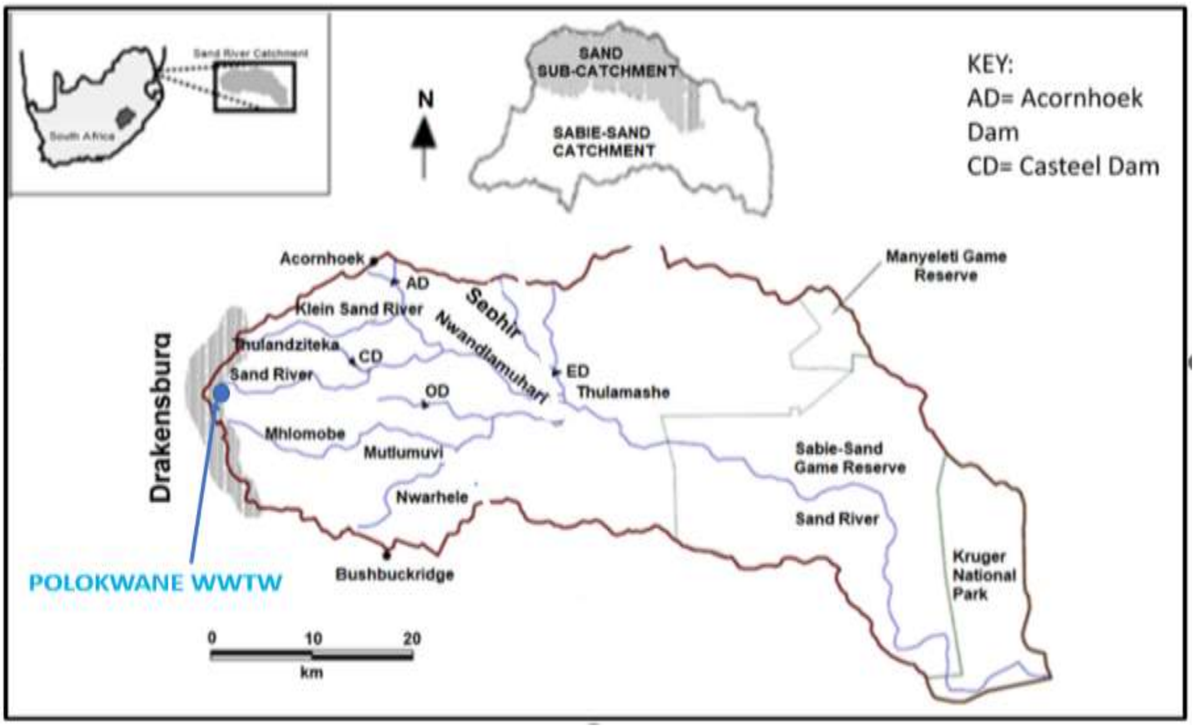

Figure 3.1: The sub-catchment of Sand River indicates the boundaries of the catchment, existing dams, major rivers, and game reserve boundaries (Seanego, 2013).

The initial plan was to conduct this study at Olifants River at the following geographical locations (S 25º 50' 36" and E 29º 15' 57"), in the vicinity of the Riverview area at eMalahleni Local Municipality, to highlight the human capacity shortfall and compare it with the sand river catchment (Figure 3.2). The Olifants River catchment covers over

54 570 square kilometers (km2) in total (Figure 3.2), and the basin is divided into nine sub-catchments (Le Roux et al., 2012; Water Research Commission, 2001). The river is fed in the highveld by various prominent tributaries, including Klein Olifants, the Elands River, the Wilge River, and Bronkborstspruit (Water Research Commission, 2001). The catchment basin receives approximately 2400 million cubic meters of yearly mean rainfall (Water Research Commission, 2001).

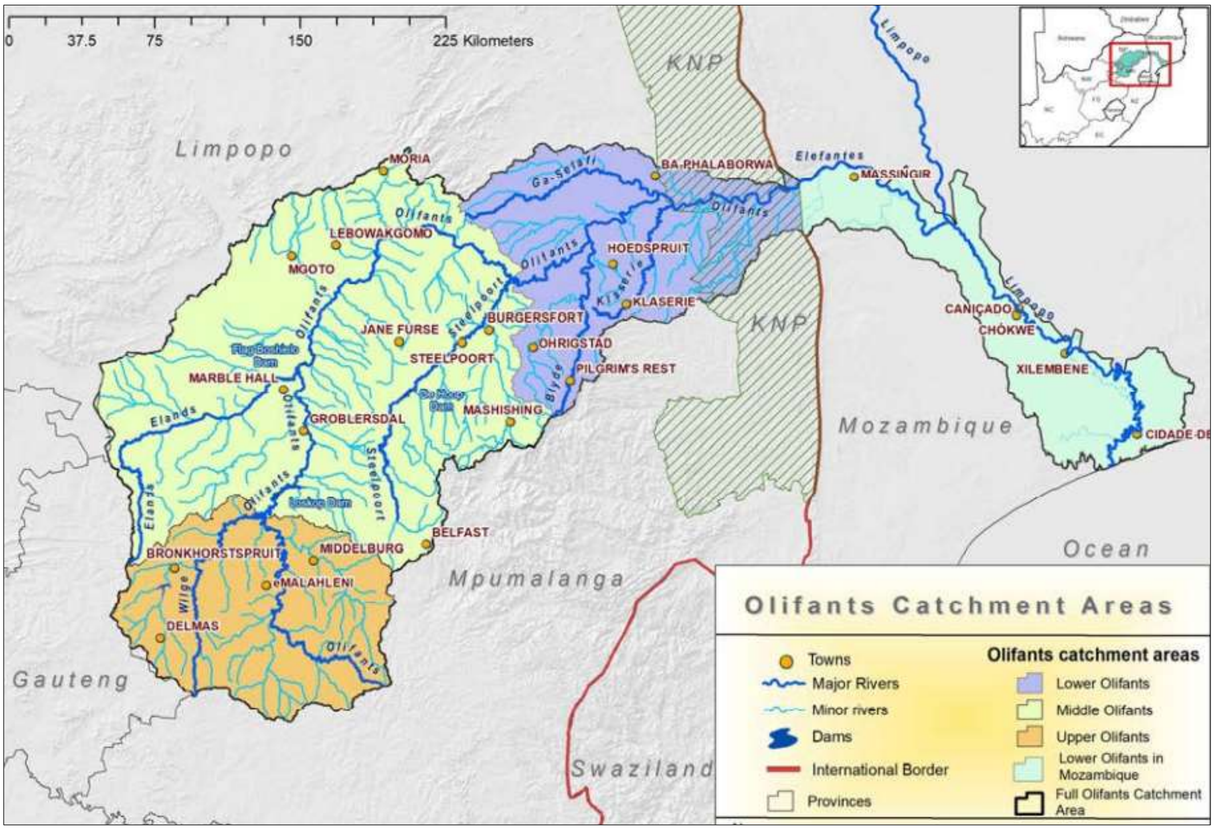

Figure 3.2: Olifants River Catchment Map showing the upper, middle, and lower regions of the catchment (USAID, 2020)

However, due to the gap in historic water quality monitoring data, it was observed that more than this study area would be needed to achieve the aims, and the non-availability of data falls within the prescribed period of this research. The investigation discovered that it has been several years since the department has been doing quality monitoring in this area. This was due to the technical and financial issues related to laboratory service contracts. Hence, the area was changed and is brought to the document to indicate that aspects outside this study's scope also play a major negative role in managing and regulating water resources.

3.2. Materials and methods

The reagents and instruments for the sample analysis at an accredited laboratory regarding the South African National Accreditation System (SANAS) requirements were analysed as summarised in sub-sections 3.3.2 and 3.3.3. of this research below.

3.2.1. Desktop study

The effectiveness of DWS's institutional structure on effective regulation was evaluated from the standpoint of legislation. This assessment considered the factor that the effectiveness of the Green Drop Program is a value chain; it tiers the systems within the department, the personnel, functions, and water service authorities. The study aimed to determine the gaps in the entire value chain that affect the effectiveness of incentive-based regulation, regulation, and water resource management and protection.

Secondly, the desktop data in this study were also reviewed by examining historical data gathered on a database known as the Integrated Regulation Information System (IRIS) from the National Department of Water and Sanitation. This data was used to determine the WWTW's historical performance and how much pressure the WWTW placed on the receiving river systems. Further, to that view, the actions taken by the responsible authority to enable the discharge of partially treated effluent into water resources The municipality used in this study is Polokwane Local Municipality, which has all facilities that discharge into Sand River. To determine whether these facilities have an overall impact on the quality of water resources and river ecology that should worry regulators, this performance is assessed from 2018 to 2022.

Thirdly, this study looks into case-related problems to validate the discoveries regarding legislation, DWS structure, systems, personnel, and functions.

3.2.2. Case Study: Sample collection

The physical water samples were collected upstream and downstream of the Polokwane WWTW's discharge site in the Sand River. The sampling locations were the DWS monitoring points that are now in situ at the upstream and downstream discharge points as well as the discharge point of Polokwane WWTW. Sample collection was done in July 2022. This period was chosen because, during this time, the winter season with limited precipitation could dilute chemical water variables due to the volume of water conveyed during a rainfall event. As a result, this time allows for a reasonable assumption about the findings on the river's water quality obtained during this time. To ascertain the contribution of WWTW effluent to the water quality of the river system, samples were collected for physical, chemical, and microbial examination.

The new data was compared with the historic data to identify changes and variations in water quality in the region.

3.3. Water Quality Analysis

3.3.1. Physical parameters analysis :

Physical parameters such as pH, electrical conductivity (EC, s/cm), and temperature (°C) were measured and analysed onsite using a portable Hach multi-probe meter Model HQ40d, calibrated before use. The onsite measurement values for these parameters were recorded on prepared sheets.

3.3.2. Chemical parameters analysis:

Nitrate: The Cadmium Reduction method was used as detailed in the Hach Water analysis manual to calculate nitrate concentration in water samples. It is a colourimetric procedure, a spectrophotometer at a wavelength of 543 nm was employed.

Ammonia: A Hach Nessler method calculates ammonia levels using reagents. The sample underwent preliminary distillation and a spectrophotometer with a 425 nm wavelength.

Chemical oxygen Demand: During digestion, COD was oxidised by potassium dichromate, sulphuric acid, potassium hydrogen phthalate, and potassium dichromate. Using a spectrophotometer, the material was assessed at a wavelength of 610 nm.

Phosphate: The amount of phosphate in water samples was determined using the Hach Ascorbic acid procedure 10209. Due to the colourimetric nature of the ascorbic technique for phosphate determination, a spectrophotometer with an infrared phototube at 880 nm.

Total suspended solids: Hach gravimetric technique 8158 assessed the total suspended solids by measuring the weight differential between the empty disc and the disc containing the remaining components.

3.3.3. Microbial analysis

Escherichia coli: The m-TEC approach uses a two-step process to identify *Escherichia coli* in samples of recreational waters, using lactose fermentation and urease-negative colonies that are yellow or yellow brown.

3.3.4. Statistical analysis

The population mean's likelihood to differ from a sample mean is indicated by the standard error of the mean, or simply standard error (Bhandari, 2022). It reveals how much the sample mean would change if the same research were repeated with fresh samples drawn from a single population. The most frequently reported kind of standard error is the standard error of the mean (SE or SEM) (Bhandari, 2022)

The standard deviation and sample size determine the standard error of the mean (Bhandari, 2022). Then the formula that the sample size and standard error are inversely related (Bhandari, 2022). This implies that the sample statistic will be closer to the population parameter, the larger the sample, the smaller the standard error (Bhandari, 2022).

Therefore, the formula below determines standard error if the population standard deviation is known (Bhandari, 2022).

$$\boldsymbol{SE} = \frac{\sigma}{\sqrt{n}} \qquad (0)$$

Where, ***SE*** is the standard error, σ is the population standard deviation and n is the number of elements in the sample (Bhandari, 2022)

Then, the formula below estimates standard error when the population standard deviation is unknown (Bhandari, 2022). This formula uses The sample standard deviation as a point estimate for the population standard deviation (Bhandari, 2022).

$$\boldsymbol{SE} = \frac{s}{\sqrt{n}} \qquad (0,1)$$

Where, ***SE*** is the standard error, s is the sample standard deviation and n is the number of elements in the sample (Bhandari, 2022).

Therefore, the confidence interval is the optimum format for presenting the standard error because readers will not need additional calculations to generate a useful interval (Bhandari, 2022). A confidence interval is a range of values where if you were to repeat your study with fresh random samples, an unknown population parameter is predicted to lay most of the time (Bhandari, 2022). Where, 95% of all sample means with a 95% confidence level will be expected to lie within a confidence interval of ± 1.96 standard errors of the sample mean.

Confidence interval formula (0,2)

$$CI = \bar{x} \pm (1.96 \times SE)$$

$\bar{x}$ = sample mean = 550
SE = standard error = 12.8

Lower limit	Upper limit
$\bar{x} - (1.96 \times SE)$	$\bar{x} + (1.96 \times SE)$

3.4. Method of analyses

The several methods project has been reviewed for comparative and correlation analysis to determine the relationship between effluent data results (percentage compliance) and green drop scoring. To depict the correlation between these variables, which enables the exploration of the implications thereof. According to Hofstetter et al. (2002), several tools are available to assess the environment. These tools include but are not limited to life cycle assessment (LCA), risk trade-off analysis (RTA) or comparative risk assessment of alternative (CRAoA), programmatic comparative risk assessment (PCRA) (Hofstetter et al., 2002), control division unit (CDU) (Figure 3.4), cumulative risk assessment (CRA), and construction management platform (Wang et al., 2017). Most of these tools have been utilised in numerous studies for comparative analysis to achieve different objectives (Wang et al., 2017; Hofstetter et al., 2002).

For the intended purposes, this research seeks to achieve the cumulative risk assessment (CRA), have been chosen and utilised as the method of analysis. This is a platform wild used in the management of water resources, which incorporates the following methodologies in combination with data on water quality to accomplish cumulative risk grading on various temporal and special scales.

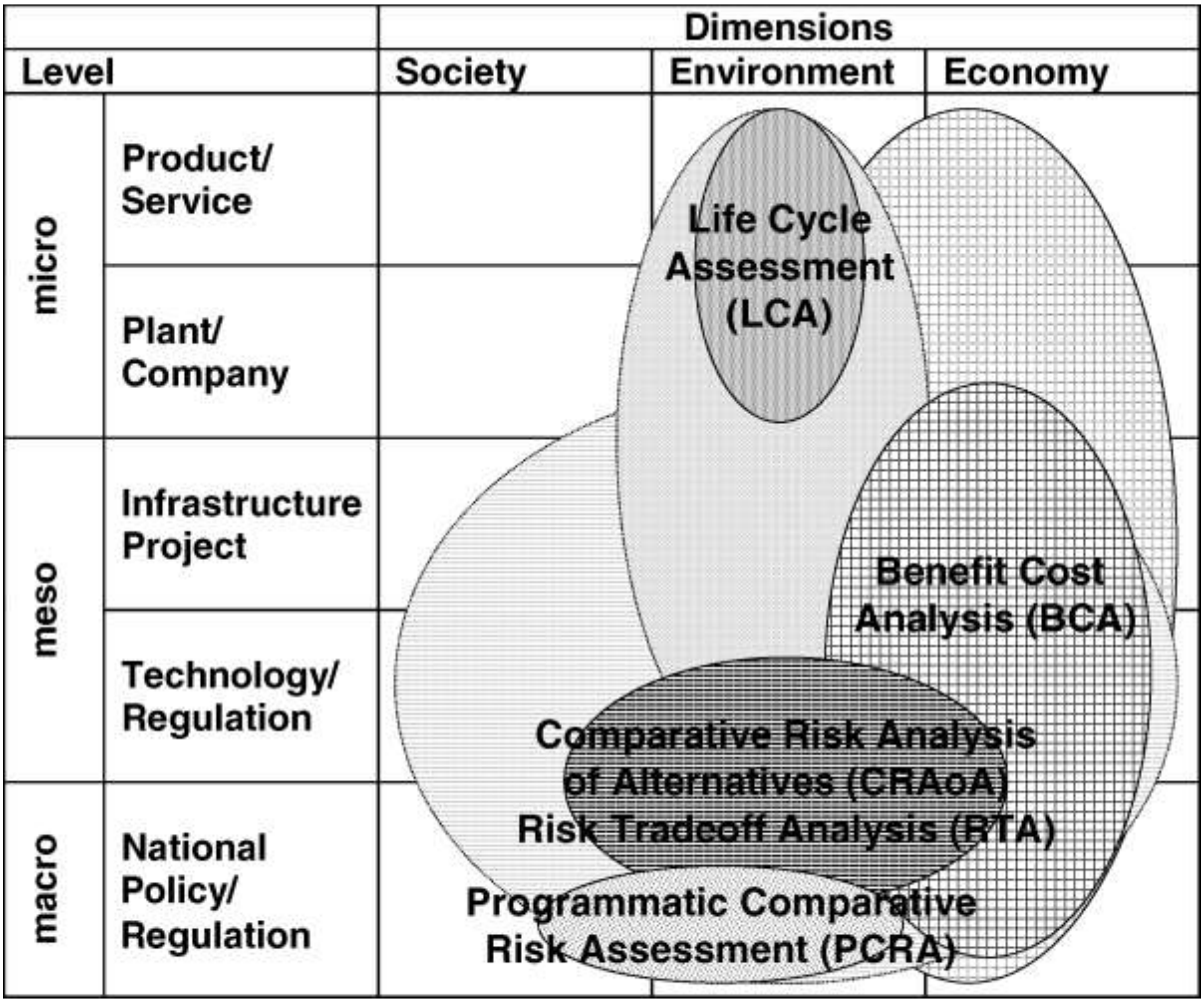

Figure 3.4: Comparative analysis and positioning of tools based on dimensions ranging from micro to macro, as well as analysis of the dimensions ranging from society to economy (Hofstetter et al., 2002).

3.4.1. Cumulative Risk Assessment System

This system employs the Pressure-State-Response (PSR) framework model, which accepts the observation of relationships between environmental pressures, the state (decision makers), and their responses (Skivington, 2017; Wang et al., 2017). Most organizations and government institutes widely consider the PSR model the most effective framework for applying the environmental index for environmental state and organization reports (Skivington, 2017; Wang et al., 2017). Therefore, the cumulative risk for the water environment refers to several contaminants and their discharge in different ways from pollution sources that can generate a cumulative risk for the water environment on both temporal and special scales (Wang et al., 2017). The PSR model was employed to build a system for evaluating the cumulative risk of water resources in the Sand River sub-catchment near the Polokwane WWTWs, considering the properties of the water resources in the research region.

Generally, the risk assessment entails gathering formal data for the intended activity, followed by predicting its intended result. This study chose a risk-based approach because it aids decision-making and is a valuable management tool because it helps set comparative priorities and allocates capital and resource expenditures (Skivington, 2017). Both risk assessment and a cumulative risk rating are part of the approach used in this study. Although risk assessment considered several phases, including the description of the intended outcome, hazard identification, consequences identification, consequences magnitude and probability calculation, risk estimation, risk evaluation, and risk assessment. But, for this study, that takes the form of recommendations in the last chapter. If the technique for this study were for government institutions, that method would include the risk management stage. (Skivington, 2017). Tables 3.1 and 3.2 below were used to assess the risks associated with wastewater discharge into Sand River and other related factors at the selected wastewater treatment facility.

Table 3.1: Risk Criterion System (Skivington, 2017)

AREA AT RISK	DESCRIPTION OF RISK	HAZARD CATEGORY					
		1 VERY LOW RISK	2 MINIMAL	3 MEDIUM	4 CRITICAL	5 VERY CRITICAL	6 CATASTROPHIC
PLANT	Large Plant Eml R X 10^4	0,1	1,0	1 To 10	10 To 100	100 To 1 000	1 000
	Small Plant Eml R X 10^4	0,01	0,1	1	1 To 10	10 To 100	100 To 1 000
	Effect On Personnel	Near Miss Incident	Minor Injury Only	Injuries	1 To 10 Chance Of Fatality	Fatality	Multiple Fatalities
WORKS	Damage	None	None	None	Minor	Appreciable	Serious
BUSINESS	Business Loss	None	None	None	Minor	Severe	Total Loss Of Business
PUBLIC	Damage	None	None	Very Minor	Minor	Appreciable	Widespread
	Effects On People	None	None (Smell's)	Minor	Some Hospitalisation	1 In 10 Chance Of Public Fatality	Fatality
	Reaction	None	None/Mild	Minor Local Outcry	Considerable Local And National Press Reaction	Severe Local And Considerable National Press Reaction	Severe National (Pressure To Stop Business)
GUIDE VALUES OF PUBLICLY ACCEPTABLE FREQUENCIES		10/Year (10)	1/Year (1)	1/10 Years (0,1)	1/100 Years (0,01)	$1/10^3$ Years (0,001)	$1/10^4$ Years (0,0001)
LOSS	Large Plant R1 X 10^3	1 000	1 000	1 000	1 000	1 000	1 000
RATE/YEAR	Small Plant R1 X 10^3	100	199	100	100	100	100

Table 3.2: Estimation of risk from consideration of the magnitude of consequences and probabilities (P Skivington, 2017)

	Magnitude of Consequences			
Probability	***Severe***	***Moderate***	***Mild***	***Negligible***
High	High	High	Medium/low	Near zero
Medium	High	Medium	Low	Near zero
Low	High/medium	Medium/low	Low	Near zero
Negligible	High/medium/low	Medium/low	low	Near zero

On the other hand, the results from the risk approach above were confirmed with the cumulative risk rating approach, which is the current tool used to assess the risks posed by WWTW in water resources (DWS, 2022). The confirmation was applied to provide certainty and a relative degree of confidence in the outcome of this study. Based on four (weighted) risk indicators, including design capacity, capacity exceedance, final effluent failures, and technical skill status at each WWTW, the Cumulative Risk Rating (CRR) score is calculated (DWS, 2022). The following formula was used to define the risk and calculate it:

$$\text{Cumulative Risk Rating (CRR)} = (A \times B) + C + D \qquad (1)$$

Where: C = number of non-compliant effluent quality parameters at the point of discharge to the receiving water body; D = number of technical skills gaps (supervision, operation, maintenance) by Regulation 2834 and Draft Regulation 813; A = hydraulic design capacity of the treatment plant in ML/day; B = operational flow as% of the installed design capacity.

% CRR/CRRmax provides for the variance of a CRR value against the maximum CRR value, and it could be reached if all four indicators are in a critical state. Using the categorizations in Table 3.3, calculate the CRR_{min}, CRR_{max}, and %CRR using equations 2–3 below (DWS, 2022).

$$CRR = (2 \times 3) + 6 + 2 = 14 \qquad (2)$$

$$CRR_{max} = (2 \times 5) + 8 + 4 = 22 \qquad (3)$$

$$\%CRR/CRR_{max} = (14/22) \times 100 = 63.6\% \text{ 2) WSA} \qquad (4)$$

Table 3.3: Cumulative Risk Rating Criterion (DWS, 2022)

	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

	C: Technical Skills Compliance	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

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

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

Risk indicator D for effluent quality (8x):

1. Microbiological: Faecal coliform or Escherichia coli
2. Physical: pH, EC, SS
3. Chemical: COD, NH_3-N, NO_3-N, O-PO_4

CHAPTER 4: RESULTS AND DISCUSSION

4.1. Case Study for the Sand River Catchment

Testing the effectiveness of the Green Drop Program, which is continuously being implemented across the country is paramount. The mining, industrial, and agricultural sectors were not included in this study's examination of the Sand River Catchment for contamination from wastewater treatment facilities. The exclusion of these sectors is attributable to the fact that they are semi-public or private entities and are not affected by the requirements of cooperative governance, making them easy to regulate. The primary wastewater treatment facilities that primarily contribute to effluent discharge into the Sand River were the focus of the case study. In the drainage region A71A, Polokwane WWTW collected water quality data for July, shown in Table 4.3.

To verify the efficacy of the Green Drop initiative, effluent discharge from the Polokwane Wastewater Treatment Plant in Sand River was utilized as a baseline. Due to the insufficient DWS internal water quality data, this watershed was chosen to replace the Olifants River basin. The Riverview WWTWs had a lot of undetermined variables for this study. Nonetheless, the Olifants River Catchment at Riverview WWTW has been evaluated in the context of the country's overall performance. This analysis considered data on the upstream and downstream water quality and the final effluent at the discharge point. To attain the "Green Drop" designation, this facility must fully comply with the water usage licensing requirements and score above 90%.

Table 4.1: Water Quality Data Discharged into Sand River from Polokwane WWTW

WATER QUALITY ANALYSIS (July)																
Variable	**Limits**	07/07/2022			12/07/2022			19/07/2022			25/07/2022			Month Average		
		U/S	***D/P***	***D/S***	***U/S***	***D/P***	***D/S***	***U/S***	***D/P***	***D/S***	***U/S***	***D/P***	***D/S***	***U/S***	***D/P***	***D/S***
COD (mg/l)	75,00	30,0	122,00	84,00	20,00	198,00	175,00	31,00	183,00	124,00	25,00	149,00	130,00	26,5	163,00	128,25
pH	5,5-9,5	8,22	8,07	7,63	8,30	7,67	7,79	8,20	7,57	7,84	7,89	7,67	7,97	8,10	7,75	7,81
Cl (mg/l)	0.25	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
NO_3^- (mg/l)	15	5.6	0,0	0,20	3,10	0,30	0,20	1,80	0,10	0,10	1,90	0,10	0,20	3,10	0,13	0,18
NH_3 (mg/l)	6	0,25	33,25	18,0	0,25	25,50	26,00	0,25	46,50	26,00	0,50	14,00	13,25	0,31	29.81	20,81
PO_4 (mg/l)	10	0,30	8,90	8,80	1,30	14,50	12,20	1,20	13,90	10,40	0,08	9,70	6,30	0,72	11,75	9,43
E. coli (per 100 ml)	100	17	248000	198000	28	320000	184000	25	384000	218000	9	271000	79000	19.8	305750	169750
SS (mg/l)	25	6	88,00	48,00	26,00	88,00	70,00	2,00	70,00	68,00	12,00	58,00	54,00	11,50	76,00	60,00
EC (mS/m)	150	100,65	131,10	126,50	102,90	143,80	137,90	98,60	135,30	129,50	25,00	149,00	130,00	81,79	139,80	130,98

U/S; Upstream, D/P: Discharge point, D/S: Downstream, nd: Not determined

4.1.1. Design and operation capacity

During the facility visit, it was discovered that the facility's design capacity was 25 ML/day. Still, the facility operates at a capacity of 40–50 ML/day and 70–80 ML/day during the rainy season. The works are operating above their design capacity, which is presumed to be because of the recurring new community and housing developments around the city. The disadvantage is that, when a wastewater treatment facility operates above its capacity, it overloads, resulting in raw, untreated sewage overflowing into surface water resources.

4.1.2. Management of the facility

The WWTWs were supervised and controlled by qualified and experienced licensee employees who have an adequate number of process controllers under their control by Regulation 2834, dated 27 December 1985, and Section 26 of the Act, to always ensure proper operation of the works and processes; as well as qualified and experienced mechanical and electrical artisans who are always available to be called in for inspection and maintenance of the work. However, it was further observed that in this situation, the plant has nothing to do with the personnel, but rather everything to do with management, monitoring, and the allocation of funds within the municipality because the municipality has been building an additional capacity since around 2016/17 and is not yet complete.

4.1.3. Effluent Quality discharged to Sand River

Sand River receives the effluent discharge from Polokwane WWTW, which is observed to introduce pollution in organic content. For example, when looking at the average results for July 2022 (table 4.1), the parameters that exceed the limits vary from upstream to downstream and at a discharge point.

Several parameters do not meet the facility's set standard, such as the COD of 128.25 mg/l, which exceeds the required limit of 75 mg/l by 53.25 mg/l monthly (Table 4.1). This indicates that the wastewater has a high COD concentration, posing a risk of dissolved oxygen depletion in the water. Thus, the aquatic ecosystem is harmed, and the facility does not adhere to environmental rules. A study conducted by Atlas Scientific shows that low dissolved oxygen levels (6.5 mg/L) quickly turn the water into a toxic environment for fish and other aquatic species because they are necessary for their survival (*Causes of Low Dissolved Oxygen in Water*, 2022). Secondly, the parameters ammonia (NH_3), *E. coli, and* suspended solids also sit above the limits with 20, 81 mg/l, 169 ml per 100 ml, and 60,00 mg/l, respectively. Additionally, the performance of the microbiological criteria at this facility during the previous three years has been less than 50%, as shown in Table 4.1 above and Table 4.4 below

Table 4.2: Average Water Quality for the Month of July 2022

Variable	Limits	Month Average		
		U/S	*D/P*	*D/S*
COD (mg/l)	75,00	26,5	163,00	128,25
pH	5,5-9,5	8,10	7,75	7,81
Cl (mg/l)	0.25	nd	nd	nd
NO_3^- (mg/l)	15	3,10	0,13	0,18
NH_3 (mg/l)	6	0,31	29.81	20,81
PO_4 (mg/l)	10	0,72	11,75	9,43
E. coli (per 100 ml)	100	19.8	305750	169750
SS (mg/l)	25	11,50	76,00	60,00
EC (mS/m)	150	81,79	139,80	130,98

U/S; Upstream, D/P: Discharge point, D/S: Downstream, nd: Not determined, compliant and non-compliant

The following calculation (as derived using equations 0,1 and 0,2 above) provides a rough idea of how well the sample data captures the entire population by determining the sample standard error associated with the average results in Table 4.2 above. The associated standard error of each of the samples from the discharge point of the Polokwane wastewater treatment works analysed is tabulated in Table 4.3 below.

$$\mathbf{SD}_{\text{Sample (COD)}} = \sqrt{\frac{\sum|\mathcal{X}-\bar{x}|^2}{n-1}}$$

$$\mathbf{SD}_{\text{Sample (COD)}} = \frac{\sqrt{\sum 1681+1225+400+196}}{4-1}$$

$$\textbf{SD}_{\text{Sample (COD)}} = \frac{\sqrt{3502}}{3}$$

$$\textbf{SD}_{\text{Sample (COD)}} = \frac{1167}{3}$$

$$\textbf{SD}_{\text{Sample (COD)}} = 37.17$$

Therefore, the standard error is derived from the sample standard deviation for all the average parameters in Table 4.2 above. These sample standard errors are presented in Table 4.3 below, together with the confidence interval.

$$\boldsymbol{SE}_{Sample} = \frac{\mathcal{S}}{\sqrt{n}}$$

$$\boldsymbol{SE}_{Sample} = \frac{34.17}{\sqrt{4}}$$

$$\boldsymbol{SE}_{Sample} = \frac{34.17}{2}$$

$$\boldsymbol{SE}_{Sample} = 17.09$$

Confidence interval formula

$CI = \bar{x} \pm (1.96 \times SE)$ $\bar{x}$ = sample mean = 163 SE = standard error = 17.09	
Lower limit	**Upper limit**
$\bar{x} - (1.96 \times 17.09)$	$\bar{x} + (1.96 \times 17.09)$
163 − (1.96 × 17.09)	163 + (1.96 × 17.09)
129,50	196.58

Using COD as an example, a 95% confidence interval (CI) of [129,50 – 196.58] indicates that there is a 0.95 possibility that the population mean chemical parameter ranger falls within this range.

Table 4.3: Statistical analysis of water quality parameters Discharge Point

Parameters	COD	pH	Cl	NO_3^-	NH_3	PO_4	*E. coli*	SS	EC
	122	8,07	nd	0	33,25	8,9	248000	88	131,1
	198	7,67	nd	0,3	25,5	14,5	320000	88	143,8
	183	7,57	nd	0,1	46,5	13,9	384000	70	135,3
	149	7,67	nd	0,1	14	9,7	271000	58	149
Average (Mean)	163	7,75	nd	0,13	29.81	11,75	305750	76	139,8
SD_{Sample}	37.17	0.22	nd	0,13	13,65	8,17	59395.896	14,69	3,19
SE_{Sample}	17.09	0.06	nd	0,12	6,82	4,09	29697,95	7,35	1,59
CI Lower Limit	129,50	7.63	nd	-1.71	16,44	3,68	246942,02	61,59	136,68
CI Upper Limit	196.58	7.87	nd	1,97	42,18	19,72	363357,98	90,41	142,92

Further, some chemical variables have harmed the Sand River's quality, as seen downstream of the WQ monitoring point and at the discharge point of treated effluent at Polokwane WWTW. These variables are NH_3, which averaged 28.81 mg/l between June and July 2022, exceeding a limit of 6 mg/l, and PO_4, which averaged 11.75 mg/l and exceeded a limit of 10 mg/l. Similarly, laboratory physical parameters such as SS (76.00 mg/l), which exceeded the 25 mg/l limit, EC (139.80 mg/l), which exceeded the 75 mg/l minimum limit, and COD (163.00 mg/l), which also surpassed the 75 mg/l limit, were all exceeded in the WUL issued to Polokwane WWTW.

These findings have been further supported by the IRIS data Tables 4.2 above and 4.4 below, which indicate the Polokwane Municipality compliance performance in running the facility and the actual quality of Polokwane WWTs. Viewing Table 4.2 above the indication appears that the municipality has been struggling to deal with operations and maintenance of their facilities. This has been observed in the fact that the municipality not only struggling with Polokwane WWTWs but with Seshego WWTW as well and they have ranged between bad and poor compliance performance and only Mankweng WWTW compliance performance which appeared to vvary from > 90% Excellent, 70 – 90% Good, 50 – 70 % Poor, and < 50% Bad, 2019 - 2022 assessment period. Then table 4.4 confirm these findings with narrowed observations from Polokwane WWTWs indicating the compliance failures of some few water quality parameters such as Ammonia, Chemical Oxygen Demand, Conductivity at 25º C, E.coli, Orthophosphate, Suspended Solids at different times during the 2022 assessment period.

Table 4.4: High-Level Failures

Determinant	Failures	Highest		
		Date	***Value***	***Unit***
Ammonia	43	2022-02-22	54.5	mg/L
Chemical Oxygen Demand	34	2022-09-06	335	mg/L
Conductivity at 25º C	17	2022-02-28	454.4	mS/m
E.coli	37	2022-04-20	498000	Count per 100 mL
Orthophosphate	6	2022-09-19	28.5	mg/L
Suspended Solids	42	2022-04-26	192	mg/L

The observations in Table 4.4 indicate that the Sand River and its ecosystem have been subjected to poor water quality in terms of high levels of COD in water resources that lower dissolved oxygen (DO) levels and can result in anaerobic circumstances that are harmful to higher aquatic life forms, faecal pollution, nutrients that indicate the potential for algae growth, and particulate matter. A study by Skivington (2017) suggests that such conditions can lead to siltation and erosion. This situation has continued for the past three years if projected based on the municipal performance in Tables 4.2, 4.3, and 4.4. Apart from the findings as far as the water quality is concerned and presented above, several issues have been discovered that play a major role in hindering the effective implementation of the green drop programme and are provided below in support of the above representation.

4.2.1. Legislative Framework

Taking account of the legislative role it plays in derailing the effective implementation of the Green Drop Programme It is paramount to reflect on the legislative provisions, sections 2, 3, 5, 24, 41, and 152(2)(b-d) of the constitution; 2, 3, 7, 151, and 152 of the NWA; 1, 11, 63, 73, and 139 of the WSA; and other related sections in these statutes as well as other relevant legislation, which display clear objectives on how water resources should be managed and protected together with what procedures should be followed. However, section 4(1)(h) of the constitution mandates that government institutions work together in a manner that fosters mutual trust and good faith. This cooperation must take the form of mutual assistance, support, friendship, communication, coordination of actions and legislation, adherence to established procedures, and avoidance of legal action against one another (RSA, 1996).

This requirement, in terms of this clause *(h)* of section 41 of the constitution (RSA) under of the corporative governance, makes sense in the sense that it avoids state resources being wasted while issues can be resolved within the state departments, which are local and national governments. At the same time, it contradicts the regulatory requirements of water users that are environmental transgressors, without proper regulation in place that monitors the extent to which the support is given to the municipality. There is also no obligatory clause that states that WSAs that are supported financially through infrastructure improvement or development must ensure that the facility operates throughout its life span, as determined by engineers; if it fails to do so and the water user pollutes the receiving water bodies, the department should institute legal action against WSA and possibly not award them with RBIG funds in the future.

Based on observations, WSAs highly abuse subsection provisions *(h)*, as they receive these funds for infrastructure improvement or development but leave the wastewater facilities infrastructure to collapse because they know they will apply for RBIG funds to DWS. However, the DWS as well has been issuing this grant to several municipalities without proactive monitoring of the projects, including the quality of the material used when refurbishing or building this infrastructure for the municipality. Again, the infrastructure development divisions do not consider the technical support divisions such as Green Drop and Compliance Monitoring when awarding these funds. Hence, the assessors, compliance officers, and enforcement officers are puzzled by facilities that last only for five years; some do not even start operations; and some take 10 years just to complete a 20 ML/day WWTW.

This section, therefore, lacks a legislative mandate that can be implemented with feasible objectives, timeframes, and actions to be taken post-support if the facility fails or collapses again. DWS lacks financial oversight in this regard because there is no proper monitoring and follow-up on the projects themselves after these funds have been awarded. The country experiences a high number of WWTWs contributing negatively to the pollution of rivers, which is associated with ageing infrastructure, and yet the DWS supports the WSAs with these funds year in and year out. To demonstrate that this is not working, privately owned facilities do not receive this support, but most of them perform far better than the municipality's WWTWs. This shows that there may be a problem with the governmental body in charge of administering and safeguarding South Africa's water resources along the full value chain.

4.2.2. DWS internal Structural arrangement

These factors that affect the effective implantation of the Green Drop Programme further extend to the technical directorates and sub-directories of the DWS organisation, which are in charge of making sure that South Africa's water resources are effectively governed, managed, utilised, controlled, and safeguarded, but are not connected or actively engage in communication. For instance, the Water Service Regulation, Compliance Monitoring, and Enforcement directorates fall under one chief directorate, but their sub-directories, Green Drop, Compliance Monitoring: Government and Institutions, and Enforcement, respectively, do not follow or have a business process that links them or makes them responsively interactive. The government and institutions, water service regulation, and infrastructural development within DWS support and regulate municipal WWTWs but do not collaborate, even though they have the same goal. There is no business process or standard operating procedure in place to link them, and as a result, one may find Green Drop assessors, CM officers, water quality officers, or even enforcement regulators one week going to the same facility for the same thing but on different days.

The same holds true for Green Drop and enforcement, and ideally, Green Drop should hand over facilities that are not authorised and that are not compliant with enforcement. Additionally, hand over any non-compliant facilities that have been approved by universities and the government, which is not currently happening. Green Drop programme sub-directorate repeatedly notifies water users through IRIS without the intention of notifying Compliance Monitoring and Enforcement (CME). If this occurs, it takes only an assessor who desires to pass it over for further compliance monitoring and enforcement action; however, nothing mandates this approach. The danger to this has not been discovered as an issue or a problem, as the Department recently endorsed a new organizational structure with the same setup. Compliance

Monitoring and Enforcement the SOP between these two directorates does exist, but it is not implemented well as it should be, and it is not properly enforced.
The management, regulation, and protection of water resources are greatly hampered by technical and structural segregation. Until such time the department decides to integrate the Green Drop sub-directorate and Compliance Monitoring: Government Institution, the mentioned issue will persist. The need for integration is such that these two sub-directorates conduct their functions in the same institution to achieve the set goals while doing the assessments. Green Drop Assessments are processed unit-focused assessments, whereas compliance monitoring audits or inspections are water use authorization-focused assessments that also include the process unit audit.

4.2.3. Database Management Systems

Similarly, the above-mentioned sub-directorates have a database management system (DMS) in their respective spaces, such as the Green Drop Programme under the Integrated Regulatory Information System (IRSI), the National Compliance Information Management System (NCIMS) for Compliance Monitoring sub-directorates, and the Enforcement Case Management System (ECMS) for the Enforcement Unit, which are not linked.

The challenge with the DMS of these sub-directorates is that they are not designed to be interactive or share information among themselves. The only existing interaction is limited to NCIMS and ECMS sub-directorates, with a handover button when a matter must be referred for enforcement. Prompt compliance responses and efficient wastewater management are difficult to achieve due to the absence of interaction between the sub-directorates such as the Green Drop Programme, compliance monitoring: Government and enforcement directorate. This is because the issues are handed over to enforcement but are not paper-trailed back and forth between these two units; hence, enforcement officials always starts afresh for each reported case as opposed to using information from forefront units such as Green Drop and Compliance Monitoring officials. This issue is an existing problem within the Department, and it does not appear to be associated with or linked to one of the factors that hamper the effective management of wastewater.

4.2.4. Government interventions

As a result of the compliance issue observed above, several interventions have been taken by the DWS upon itself to deal with the issue of the Polokwane WWTW, such as a compliance audit conducted on May 19, 2016. During that audit, the wastewater treatment works were discovered to be overloaded (operating above its design capacity), with several violations of the licenses' conditions. On December 1st, 2016, the municipality received a new water use license with amendments to previously authorized water uses and some of the conditions on the water use license issued in 2003. The municipality received a pre-directive for non-compliances on 01 June 2017, demanding that the municipality submit an action plan to the department to address all of the discovered non-compliances.

4.3. Green Drop Assessment Results

Additionally, the Green Drop Assessment conducted at various wastewater treatment facilities has revealed several non-complying facilities. Therefore, the water user (Polokwane Local Municipality) was once again found to violate the established parameters in the terms of the Water Use License issued, according to compliance monitoring audits conducted on April 21, 2021, and August 25, 2022, which also involved the enforcement department. This may imply several things, including the municipality's resistance to upholding the established standard or its financial difficulties in maintaining the facility. Additionally, heightened water quality pressure in the Sand River exposes people to health concerns and creates unfavourable conditions for aquatic life.

The Green Drop unit under water service regulations conducted 379 analyses for all three Polokwane municipal WWTWs up until August 28, 2022, with 209 failures. The unit system IRIS has shown that the microbiological, chemical, and physical tests have failed for the past three years in all three municipalities. The Mankweng WWTW complies with only the physical variables in those three years. In Polokwane and Seshego WWTWs, the microbiological yields have been less than 50% for the last three years, with chemical variables fluctuating between poor and bad performances. With all these findings, no records of them being escalated to either the compliance monitoring unit or the enforcement unit.

According to the Green Drop analysis, from the assessments from 2009 to 2011, facilities that scored less than 50% dropped significantly. From 56% in 2009 to 25% in 2011 with a moderate drop between 2011 and 2013 (3% from 25% (DWS, 2022). From 2013 to 2021, an increase of 40.91% was observed in facilities that scored less than 50% in their assessments. According to Table 4.5, 82% of the facilities assessed in 2013 received a 50% score, and 68.99% of the facilities assessed in 2021 received a 50% score. (DWS, 2022). Multiple Green Drop scores for facilities scoring 50% were 35/158 in 2013 and grew to 49/158 in the 2021 evaluation, demonstrating the decline. (Figure 4.1). All these deteriorations in WWTW's performance suggest that these facilities contribute negatively and put more quality pressure on water resources and aquatic life (DWS, 2022).

Table 4.5: Green Drop Comparative Analysis from 2009 to 2021

GREEN DROP COMPARATIVE ANALYSIS					
Performance Category	***2009***	***2011***	***2013***	***2021***	***Performance Trend 2013 & 2021***
Incentive-based indicators					
Number of municipalities assessed	20 (100%)	27 (100%)	25 (100%)	25 (100%)	→
Number of WWTW assessed	107	157	158	158	↓
Average Green Drop score ≥ 50%	47%	65%	69%	66%	↓
Number of Green Drop score ≥ 50%	46/107 (44%)	117/155 (44%)	123/158 (50.4%)	109/158 (69%)	↓
Number of Green Drop score < 50%	61/107 (51%)	38/155 (56%)	35/158 (49.6%)	49/158 (31%)	↓
Green Drop awards Certifications	10	19	26	12	↓
Average Site Inspection Score	N/A	65%	74%	69%	↓
N/A = Not Applied,			↑ = Improvement, ↓ = digress, → = no change		

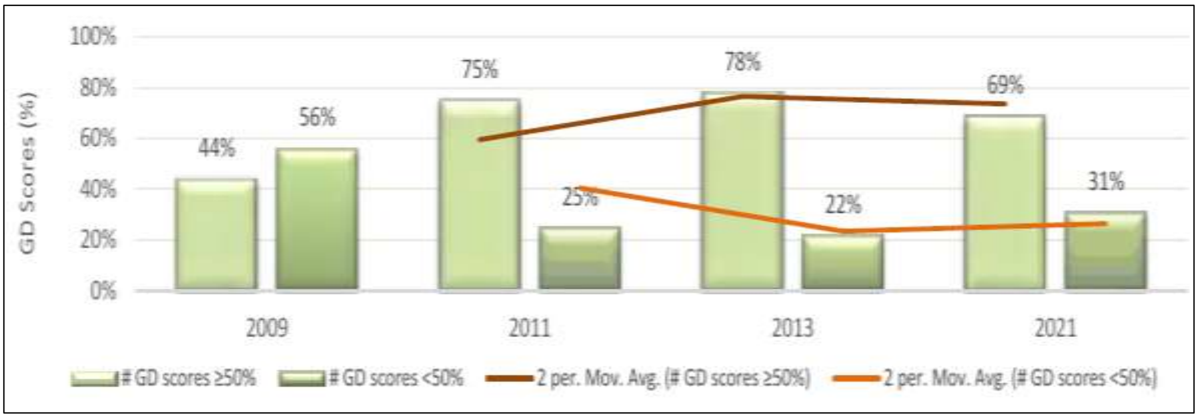

Figure 4.1: Green Drop Trend Study from 2009 to 2021, showing the proportion of GD scores above and below 50% (DWS-GD, 2022).

During the study, several wastewater treatment works were visited by DWS officials for compliance monitoring. The facilities chosen were those that scored less than 30% in the 2021 green drop assessment. During the visits, it was observed that several of these facilities needed to be operational and were discharging untreated effluent directly into water resources. The river systems that were subjected to that untreated effluent were the Kariega River in Kenton-on-Sea, the Kowie River in Port Alfred, unnamed streams in Hankey, and Thornhill, all in the Eastern Cape. The Sand River in Polokwane received partially treated effluent from the sewage works.

Furthermore, data extracted from IRIS for municipalities and private water institutions from 2019 to 2022 were analysed (Table 4.6). It was discovered that the municipal managed facilities performed poorly to badly in microbiological, chemical, and physical variables for this review period, for example, Kouga and Ndlambe local municipalities; Emalahleni's local municipality performed poorly on microbiological variables; and Steve Tshwete's local municipalities. While facilities are managed by private water institutions such as the uMgungundlovu District Municipality and the City of Ekurhuleni Metropolitan Municipality performance ranged between excellent and reasonable. For insights for the research, from this observation above, it can be inferred that proper management of water facilities needs to be enhanced to protect and develop water resources, hence increasing the security of the water supply for future generations.

Reflecting on Table 4.6 below, regarding microbiology within the water, 90% compliance is required; the same applies to chemical and physical variables. This requirement also applies in the operation of the facilities, where operational indicators refer to flows and sludge treatment volumes. These are the requirements for Green Drop Assessment; however, the IRIS emphasizes that 100% compliance with the conditions for license or permits and general authorization for authorized facilities are required for compliance monitoring.

Table 4.6: Municipalities Green Drop Assessment Overall Performance

Municipalities Green Drop Overall Performance												
WSAs (LMs)	***2019 assessment period***			***2020 assessment period***			***2021 assessment period***			***2022 assessment period***		
	Micro-biological	Chemical	Physical	Micro-biological	Chemical	Physical	Micro-biological	Chemical	Physical	Micro-biological	Chemical	Physical
Emalahleni (MP) – (10 WWTWs)	95.8%	87.0%	87.9%	26.0%	78.9%	85.5%	28.1%	78.7%	88.9%	28.0%	75.9%	91.6%
Steve Tshwete (MP) – (4 WWTWs)	10.4%	70.8%	69.4%	4.2%	78.6%	70.0%	35.4%	66.5%	73.9%	46,5%	64.5%	82.0%
Kouga (EC) – (7 WWTWs)	43.8%	0.0%	0.0%	55.6%	50.0%	61.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Ndlambe (EC) – (5 WWTWs)	71.2%	17.5%	31.6%	50.0%	28.6%	41.2%	73.7%	29.6%	29.4%	53.3%	37.9%	36.7%
Buffalo (EC) – (15 WWTWs)	43.5%	62.7%	89.1%	36.0%	64.2%	83.6%	33.5%	61.8%	78.3%	20.0%	77.0%	80.0%
Umgungundlovu DM (KZN) – (6 WWTWs)	87.3%	91.5%	90.8%	85.1%	91.4%	93.7%	87.3%	96.3%	96.0%	90.8%	95.7%	95.9%
Ekurhuleni (GP) – (17 WWTWs)	86.5%	85.3%	92.5%	84.1%	84.2%	94.1%	76.3%	80.2%	92.7%	73.0%	76.3%	92.2%
Polokwane Local municipality (LP)												
Mankweng WWTW	60.9%	59.2%	94.6%	9.1%	54.7%	94.3%	0.0%	70.0%	92.6%	2.1%	56.9%	86.7%
Polokwane WWTW	5.5%	25.3%	73.8%	2.7%	33.6%	69.3%	0.0%	47.1%	58.3%	2.5%	31.0%	52.2%
Seshego WWTW	13.0%	34.2%	68.6%	0.0%	26.1%	62.8%	0.0%	44.1%	57.8%	0.0%	32.7%	59.3%
Polokwane LM	**25.2%**	**38.7%**	**78.5%**	**4.0%**	**37.9%**	**75.3%**	**0.0%**	**54.8%**	**70.9%**	**1.6%**	**40.8%**	**66.6%**
Compliance Legend: > 90% Excellent, 70 – 90% Good, 50 – 70 % Poor, and < 50% Bad												

Upon observation, while the IRIS systems recognize the importance of water users adhering to authorization requirements, there is no standard operating procedure (SOP) for the Green Drop unit or the compliance monitoring unit. That is a gap in the water resource regulation function that seeks to achieve the same goal; neither of these units has a process flow. For example, the Water Service Regulation (Green and Blue Drops), which conducts assessments at facilities, does not refer its findings to those not authorized to the Compliance Monitoring Division for further action. Table 4.6 shows the evaluation period from 2019 to September 2022, but these were all referred for compliance monitoring and enforcement. Based on my experience within DWS, the department does not refer to these evaluations, and this is purely because no SOP is linking these units.

As a result, there is no requirement to cross-reference these units, except between compliance monitoring and enforcement which has a SOP that connects them. The lack of linkage between these units also illustrates discrepancy within the DWS's internal structures which seek to achieve the same goal of protecting water resources from pollution caused by effluent discharges from municipal wastewater treatment plants.

The shortcomings have been noted as they relate to the execution of the green drop evaluations. For example, in the municipalities, the assessment is currently done by gathering all the personnel responsible for wastewater services and assessing all of the local municipality's facilities. The catch is that during the audit, the assessor will observe based on the municipal staff's responses and decide on the facility on which to perform a site inspection—unfortunately, the findings for this specific facility impact other positive and negative facilities. For example, four of the five facilities in Kouga Local Municipality visited during this research have been non-operational for quite some time. Yet, they scored less than 30% on their 2021 assessments.

Therefore, the average used for the state of the facilities is based on one or two sites visited in a municipality, for example, that has more than ten wastewater treatment plants. This means that the municipality's performance is either above or below average, which is only sometimes an accurate reflection of what is happening in the field. For example, only two facilities are indicated as performing below average regarding microbiological, chemical, and physical parameters, and the rest appear reasonably performing (Figure 4.2). However, this partially reflects what was/is happening in the field, especially when considering a site inspection assessment in a municipality for each facility. Taking this into account, the assessment results would result in a different "green drop assessment" conducted on each facility municipality instead of inspecting one and making predictions for the rest of the municipality facilities. This is one of the gaps that hinder the program's effectiveness within the DWS.

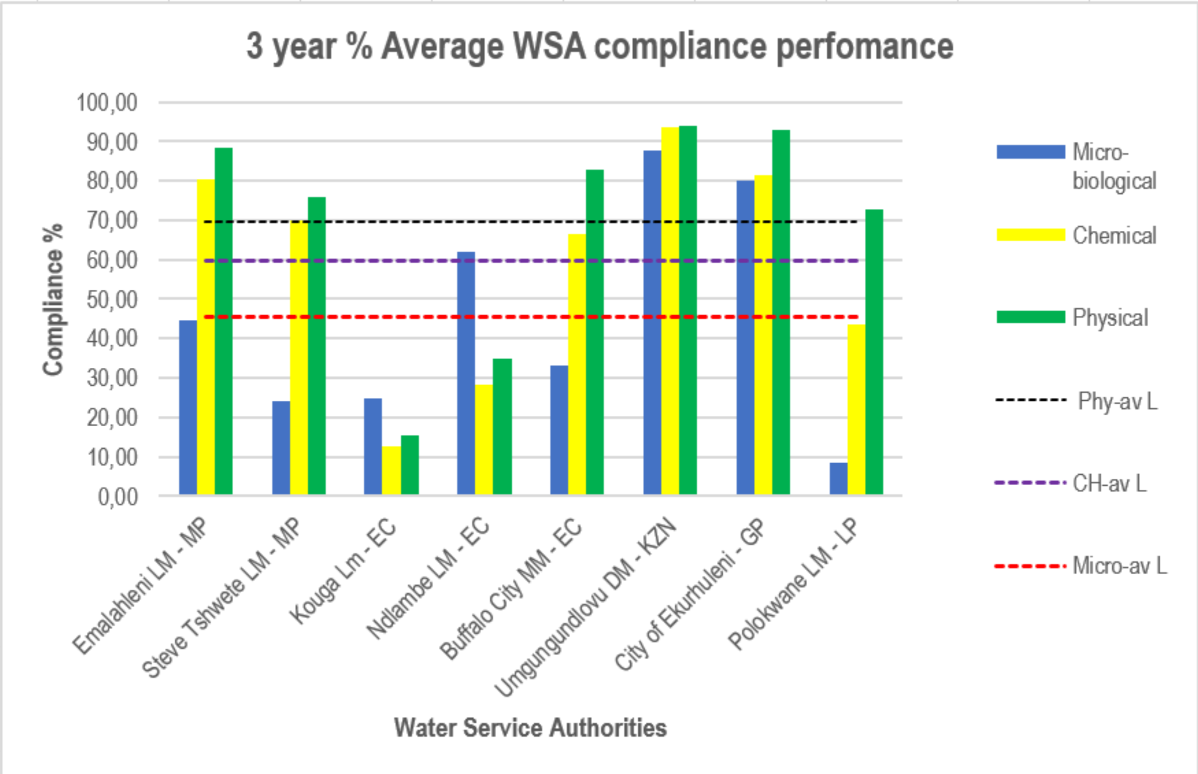

Figure 4.2: Water Service Authority (WSA) % compliance for a period of 3 years

Despite having the WWTW facilities previously mentioned, certain towns, like the Western Cape Province, obtained green drop certification, with some of the facilities achieving above an 80% score (DWS, 2022). Facilities from the following municipalities: Scores of >80% were achieved by the City of Cape Town, Drakenstein, Stellenbosch, Witzenberg, Mossel Bay, Bitou, Swartland, and Saldanha (DWS, 2022). In particular, facilities include Langebaan WWTW 90%, Riebeek Valley WWTW 97%, Gansevallei WWTW 84%, and Wellington WWTW 95% (DWS, 2022).

Looking at the analysis in Table 4.4 in comparison to the results in Table 4.2 and considering the failures in Table 4.5 above, it appears that the Sand River has been subjected to an average constant pollution of COD = 128.25 mg/l, NH_3 = 20,81 mg/l, *E. coli* = 169.750 per 100 ml, and SS = 60.00 mg/l every month for the past three years.

Additionally, the Green Drop performance score has increased for facilities performing less than 50%, which indicates that more water quality pressure is being continuously introduced to the receiving river systems. This accumulative pressure risks several areas, including river quality, aquatic ecosystem life, and human health concerns. The potential hazards to human health, river water quality, and aquatic ecosystem life were observed to be 72.3% higher in one month than they were, when they are compared with compliance performance in Table 4.6. The risks for the "water quality" of the Sand River were observed based on the approaches used in tables 3.1 and 3.2. Therefore, in terms of the Risk Criteria System, Sand River has been classified as having a hazard risk category of medium to critical, except that at the time of this study, no hospitalizations or fatalities were reported. This, however, may be far worse if thorough biomonitoring could be carried out to access aquatic ecological life in the river system below the Polokwane wastewater treatment works' discharge point.

4.4. Risk Assessment

The wastewater treatment facilities are designed to purify wastewater, in this case, domestic and industrial, and the overall intention is based, among other things, on reducing organic content, faecal pollution, and suspended solids. The quantity of treated effluent discharged into a water resource has specific standards for each authorised facility. It is not exempt from complying with general water quality standards if not authorised. This is done to limit the pollution of water resources or the environment at large. Therefore, subsections 4.5 using Tables 4.7–4.11 below are utilised to measure the risk at the Polokwane WWTW using different risk assessment factors to enable anticipated risk categorisation of the facility.

Table 4.7: Risk Assessment Measure

This table below evaluates the risk using the hazard categories in Table 3.1 above, specifically, the Polokwane wastewater treatment works. This evaluation determines the significance of the estimated risk to those anticipated concerns.

Area at Risk	Risk description	Hazard Category	Comment
WWTWs	Large Facility	4	
	Effects on personnel	3	Chances of injuries to take place the plan due to aged infrastructure
Works: Process Units	Damage	6	The damage at works is so serious to an extent it requires agent attention
Public	Damage	4	Currently, damages to the public are minor but severe to the aquatic ecosystem
	Effects on People	3	No person has been reported being hospitalised or any fatalities report yet. However, if the public can be in contact downstream of the discharge point that can affect their health.
	Reaction	4	Considerable Local and National press reaction is required urgently
Risk Categories*: Very low = 1, Minimal =2, Medium = 3, Critical = 4, Very critical = 5 & Catastrophic = 6*			

4.4.3. Hazards Identified

The following risks were discovered after looking at the water quality findings: High organic loads (COD), high ammonia flows through the sewage works and overstress the river system, high bacterial content (E. coli), and high bacterial content from the sewage works put a strain on the river system. High-suspended particles, including but not limited to those listed above and below in tables 4.8 to 4.12, could disrupt the operation of the municipal sewage works.

Table 4.8: Consequences identified

Hazard	*Consequence*
High organic load	Sewage works are unable to handle the load
High salt load	This leads to elevated salinity in a river
High level of ammonia	Algal growth in the river system
High bacterial load	Faecal pollution on the river
High suspended load	Disrupts the functioning of the works

Table 4.9: Consequence magnitude estimate

Consequence	*The extent of the Consequence*	*Probability*
Sewage works are unable to handle the load	Moderate	high
This leads to elevated salinity in a river	Moderate	High
Algal growth in the river system	Mild	Medium
Faecal pollution on the river	Severe	High
Disrupts the functioning of the works	Mild	low

Table 4.10: Risk estimation

Estimated hazard	*Consequences*	*Risk*
High organic load	Sewage works are unable to handle the load	High
High salt load	This leads to elevated salinity in a river	High
High level of ammonia	Algal growth in the river system	High
High bacterial load	Faecal pollution on the river	High
High suspended load	Disrupts the functioning of the works	High

Table 4.11: Risk evaluation

Main risks estimated	***Significance***
High organic load	**High**: Facility continuously unable to meet the set legislative limits
High level of ammonia	Medium: contributes to an accumulative deterioration of water quality
High bacterial load	High: contributes to an accumulative deterioration of water quality
High suspended load	Medium: facility unable to meet the set standards

Table 4.12: Risk Assessment

Estimated Risk	***Risk Assessment***
High organic load High level of ammonia High bacterial load High-suspended solids load	Unbearable without any steps taken to address the situation

Based on these findings, it was determined that the wastewater facility that discharges treated effluent into the Sand River system appears to threaten aquatic ecosystem life, public health, and food security. Due to a high organic load, a high level of ammonia, faecal pollution, and high suspended solids discharged continuously into the river without effective measures implemented to stop this pollution, compliance monitoring audits, water quality assessments, and green drop assessments are ongoing in the facility in question. Still, no tangible results have been achieved based on projections from 2019 to date.

4.5. Cumulative Risk Rating (CRR)

The dangers from treated effluent discharge resulting from the purification of domestic and industrial wastewater were combined with the risks to water quality, aquatic ecosystem life, human health, and the environment to characterize, analyse, and quantify the risks.

Using Table 3.3, the risk analysis is described in Table 4.13 above, the cumulative risk rating (CRR) for the month was calculated using the formula below.

Table 4.13: Risk analysis and characterisation for Polokwane WWTWs

A= Design	B= Design Capacity exceedance	C= Technical Skill compliance	D=Non-compliant Parameters
The design capacity of the facility is 25 Ml/d and ranges between 21 -50 Ml/d.	Exceedance ranges between 101 – 150%.	Complies with the capacity required.	Non-compliant with 4 parameters.
WF = 3	WF = 4	WF = 1	WF = 4

Cumulative Risk Rating (CRR) $CRR = (Ax\ B) + C + D$ (5)

= (3 x 4) + 1 + 4

= 12 + 1 + 4

CRR = 17

The calculation for Polokwane Wastewater Treatment Works CRR was done based on formula number 1, and the value obtained is 17.

Therefore, the maximum cumulative risk rating is calculated using equation 1, with the maximum in table 3.3, as it is done in equation 3:

CRR_{max} = (2 x 5) + 8 + 4 (6)

= 22

The maximum cumulative risk rating is calculated for Polokwane WWTW at 22; therefore, the %CRR is calculated using equation 4.

Cumulative risk rating percentage (%) = CRR/CRR_{max} x 100 (7)

%CRR/CRR max) = (17/22) x 100

= 72.3%

The variance of a CRR value against the maximum CRR value is provided by $\%CRR/CRR_{max}$, equal to 72.3%, implying that the indicators are relatively critical. Therefore, in just one month, the facility poses 72.3% of the risks to human health, river water quality, and aquatic ecosystem life. Given that the failure rates of these parameters have remained consistent since 2019, the facility has posed a 72.3% risk to those aspects every month for the past four years.

5. CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The protection of water resources is one of the department's top priorities. It serves to safeguard future water demand, human health, and the health of terrestrial and aquatic ecosystems. This study aimed to determine how well the Green Drop Program's audits and assessments linked to the DWS's regulatory framework. Through competent staff, disciplined thought, and collaborative action monitoring and reporting to South African citizens annually, this program or process aims to inspire a route that results in sustainable, compliant wastewater services. However, since its inception in 2008, this study has discovered aspects that have hampered the implementation of this incentive-based regulation for municipal wastewater facilities. The factors that impede a complete, adequate, and successful green drop program include organizational arrangements within DWs, including capacity, work, and database system arrangements; the use of a blanket approach when conducting green drop assessments and not inspecting every facility; a lack of accountability in both municipalities and DWs when it comes to infrastructure grants such as RBIG and other related aspects; and the regulatory aspect requirement of cooperating. As a result of partially or untreated effluent discharge, among other sectors of municipal wastewater treatment, several rivers in the country are experiencing contamination and water quality pressure.

On a positive note, the requirement in terms of Section 41 seeks to save state resources from being shared among themselves. The flaw discovered is that it needs to specify how much support each government department must provide to each other. For example, the DWS has designated funds set aside to assist the municipality with infrastructure refurbishment and development, such as regional bulk infrastructure grants (RBIG). Despite the availability of these grants, the municipal wastewater treatment system continues to deteriorate, as evidenced by the 2022 Green Drop Report results, with the municipality bearing little responsibility to meet DWS halfway in this regard.

This research examined whether Polokwane WWTW's release of treated effluent into the Sand River complied with the water user's license. Considering when one facility had compliance failures on some parameters for four years, the Green Drop program could be more effective with assessments done every year. For example, compliance with water quality standards has been monitored for a month compared to the municipality's performance in previous years. It was discovered that the Sand River has been subject to an average constant pollution of COD = 128.25 mg/l, NH_3 = 20.81 mg/l, E. coli = 169.750 per 100 ml, and SS = 60.00 mg/l every month for the past four years. This research period has yet to be observed, which could lead to change, not only with the Green Drop Program but also with the other components, such as compliance monitoring and water quality management. Lastly, it was discovered that the facility poses a 72.3% risk to human health, river water quality, and aquatic ecosystem life within a month. Considering that the failures of these parameters have been the same since 2019, it implies that the facility has been posing a 72.3% chance of risk to those aspects every month for the past four years.

5.2. Recommendations

The municipality outsources the operation and management of water service facilities, primarily wastewater treatment works, to independent water management institutions. These water service institutions are excluded from regulation under Section 41 of the Constitution, making them simple to regulate and successful thus far, as evidenced by those in charge of the City of Ekurhuleni Metropolitan Municipality and uMgungundlovu District Municipality's wastewater management facilities (see Table 4.6).

Secondly, the DWS needs to integrate the internal structures or link sectors responsible for monitoring and regulating municipal water service facilities. For wastewater regulation, the department should make the Green Drop unit a point of entry where all the performing facilities are to be incentivized to do more, and those that do get to improve should be referred to compliance monitoring for those that are authorized and to enforcement for those that are not authorized. Refer to WQM for those with minor compliance issues in terms of quality. Also, use IRIS as the umbrella body of the data and work-based systems, where all these systems are linked with specific, limited relevant access rights, among other things such as viewing, downloading, and uploading. For example, between NCIMS and ECMS, the NCIMS users from compliance monitoring should have only the viewing and handing over rights to ECMS. The ECMS users from enforcement should have the viewing and reporting downloads on NCIMS. Furthermore, all these sectors should be able to access eWULAAS to check the authorization status and have rights to download WUL, more or less as shown in Figure 4.3 below. All these interactions between these systems should be guided by standard operating procedures (SOPs).

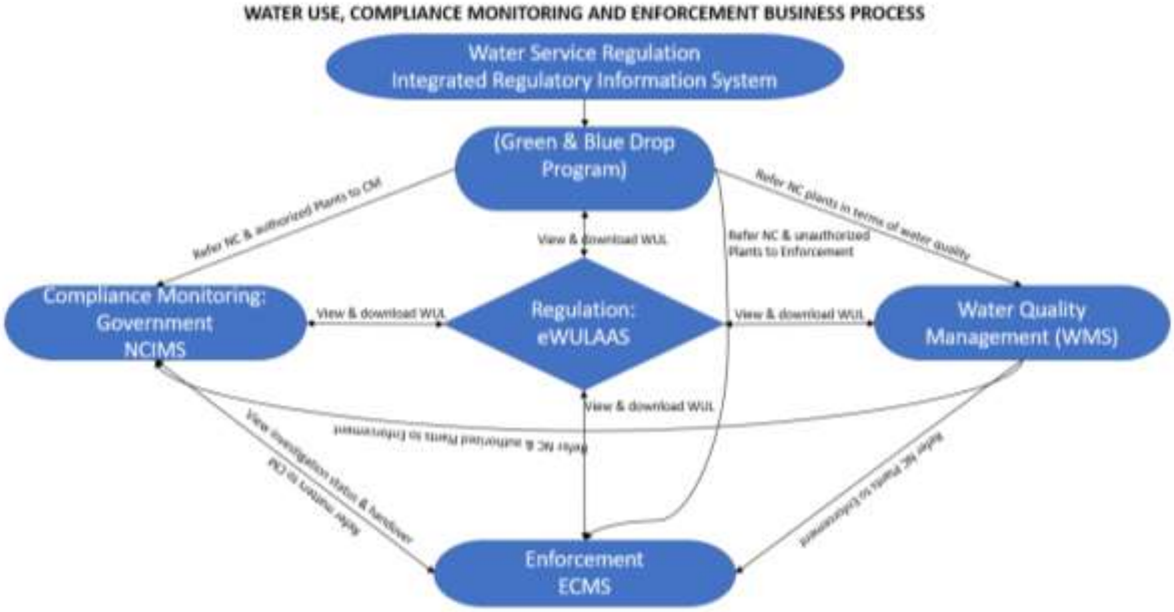

Figure 4.3: Proposed Business Process

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