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Evaluating the Effectiveness of the current Water Resource Management Approaches in Maintaining the Requirements of the South African Guidelines for Aquatic Ecosystem: A study of Hennops River

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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 in Environmental Sciences to the University of Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

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(Signature of candidate)

29 day of June 2020 at the University of the Witwatersrand, Johannesburg

ABSTRACT

Surface water resources management in the past has been coordinated on a centralized level. Currently management of this water resource is a decentralized ordination. The decentralization has seen great legislative development. The National Water Act no.36 of 1998 has brought about many changes in the water resources management field ranging from institutional arrangement to policies, strategies and water use guidelines. This study evaluated the effectiveness of the current water resource management approaches in maintaining the requirements of the South African Water Quality Guidelines for aquatic ecosystems. The study area evaluated was Hennops River, focusing on the parts of the River that pass-through Centurion, due to the controversy related to its sewage pollution. Methodologies employed during the study period consisted of literature review, water quality data analysis, interviews and questionnaire and observation conducted along the study area with photographs taken.

It was found that Hennops River is at great risk of direct pollution by both authorized and non-authorized water users. The catchment management agency within the study area was also found to be un-operational. Furthermore, it was also found that the water quality-monitoring programme by The Department of Water and Sanitation had been suspended, and therefore there were no water monitoring results available for our analysis. The study noted that the water quality-monitoring programme has been acknowledged globally as a critical water resource management tool. The suspension of the water quality-monitoring programme by The Department of Water and Sanitation is thus noted as a major step back in the water resource management field. Therefore, research findings strongly recommended the urgent need by regulating authorities to review the South African Water Quality Guidelines: Aquatic Ecosystems and National Water Resources Strategy, which will ensure progressive development of the said documents and management thereof of water resources.

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LIST OF ABBREVIATIONS

AEV- Acute Effect Value

CEV- Chronic Effect Value

CMS- Catchment Management Strategy

CMA- Catchment Management Agency

COJMM- City of Johannesburg Metropolitan Municipality

DEA- Department of Environmental Affairs

E.COLI- Escherichia Coli

GL- General Limit

IRR- Institutional Reform and Realignment

NEMA-National Environmental Management Act

NWA- National Water Act

SL-Special Limit

TWQR-Targeted Water Quality Range

WWTP- Waste Water Treatment Plant

WMA- Water Management Area

WQM- Water Quality Management

WWF- World Wildlife Fund

WMS- Water Monitoring System

CHAPTER ONE

FRAMES OF REFERENCE

1.1. INTRODUCTION

Water is a basic human need which forms part of the natural water cycle. The definition of water has changed over time with every researcher defining it in such a way that fits the context of their research. Oki and Kanae (2006) defined water as "a naturally circulating resource that is constantly charged" while Biswas (2004) defined water as "a resource that is of direct interest to the entire population, as well as to most ministries of development and state levels". While a variety of definition of the term "water" have been suggested, in the context of this study the latter definition is applied. Looking at the two definitions, the central question would then be: what is a resource? A resource in simple terms refers to a source or place of origin where "something" is obtained (Difference between sources and resource, 2015:11). Therefore, water resource, as per definition of resource, is a source of water.

Globally water resources management has caught the attention of governments with imminent challenges which are foreseen as possible future disasters (Zhao *et.al*, 2017). Water shortage, degraded water quality, with water distribution being highly uneven and water pollution are amongst some of the global water management challenges (Zhao *et.al*, 2017). Undoubtedly so, the afore-listed challenges impact directly on available water for meeting basic human needs. Efforts had been put in place to address these issues, however management of water resources and policy making does not have full representation and participation, hence some challenges are still prevailing to date (Tantoh and Simatele, 2018). Yang *et.al.* (2015) in their research paper entitled: "The relationship between China's coal resource development and water resources" notes that water as a basic need is also a foundation for social and economic development to which some other researchers agree to (e.g. Braune, 2014). When a resource has to cater for two basic needs concurrently, a well formulated management approach should be in place. Water interacts with energy exploitation, especially coal, with an implication of a possibility of deterioration in the quality and quantity of water (Yang *et.al*., 2015).

In terms of the African continent, there is admittance that water resources are impacted upon by various processes and ultimately affects the quality of surface and groundwater resources. Most countries within the African continent such as Ivory Coast, Cameroon, Ethiopia, Sudan, to list a few, water resources management have been placed at a highly centralized government level excluding communities in such management (Tantoh and Simatela, 2018). Recent evidence suggests that water resources management throughout the globe involves several different stakeholders (Tembata and Takeuchi, 2017), however the reality to this statement is far different for many sub-Saharan countries. It is a widely held view that water resources across African countries have in the past years been non- to poorly managed. Sub-Saharan countries lack extensive literature which will thus provide methods to be used for decision making that will ensure water quality is not compromised when allocating water resources for economic development (Cruz *et.al*., 2017).

South Africa is located in most parts of the globe, which are mainly associated with spatial distribution of rainfall, therefore water availability across the country is also highly uneven (Department of Water and Sanitation, 2004). Many researchers believe that South Africa is associated with scarcity of water. The South African water policy brings water resources management closer to the people by vesting the responsibility of water services to local government (Van Niekerk and Du Pisani, 2006). Although there are legislative requirements in place, water being a scarce resource makes it more critical in terms of its entire coordination and management. It is however anticipated that in future South Africa will be more dependent on surface water for most of its livelihood activities than it has during the past decades (Department of Water and Sanitation, 2004). One possible implication of poor surface water coordination and management is a potential to impact negatively on the aquatic ecosystems livelihood.

The research focused at Hennops River, only on parts that passes through Centurion area, which falls under the jurisdiction of City of Tshwane Metropolitan Municipality (COTMM). Although this research focuses on the City of Tshwane, it can also be applied to other regions in South Africa. The research methods employed were both qualitative and quantitative methods. The two said research method allowed for qualitative and

quantitative data to corroborate. The research gaps, which were deemed critical were, firstly lack of participation by government officials whose responsibilities involve surface water resources management, secondly variety of raw water quality data for wide range of constituents as listed on the South African Water Quality Guideline: Aquatic Ecosystem (SAWQG: AE).

1.2. THEMATIC CONSIDERATION

In view of the fact that water is a basic human need, a well-structured management plan is of dire importance. Tantoh and Simatele (2018) observed that institutional framework for water resources management in a larger part of sub-Saharan African region are characterized by top-down management systems. More often than not, in many sub-Saharan African countries, water resources management is done at the National level with little or no participation from local government and grassroots-communities in policy making processes.

Gauteng is the central and mostly densely populated province which is also deemed as the economic hub of South Africa, consisting of three Metropolitan Municipalities VIZ: City of Johannesburg Metropolitan Municipality (COJMM), Ekurhuleni Metropolitan Municipality (EMM) and COTMM (Tomaschek *et.al.,* 2015). In terms of the area cover, COTMM takes up to 6 345 km^2 of area with a population estimated at 3.32 million (City of Tshwane, 2018). Hennops River is located in the COTMM, South Africa with a length of 9, 11 kilometers (General overview of Gauteng, 2010). City of Tshwane as a capital city of the Republic of South Africa, hosts industries, agricultural activities, homes of diplomats and is a residential area for its citizens and a number of embassies (City of Tshwane, 2018:9). Prospects of these aspects depend on the available water for use, of a legally compliant quality.

The COTMM rely on fresh surface water for its water security, with groundwater and return flows not utilized much (Department of Water and Sanitation, 2015). The COTMM depends on surface water resource for many processes such as agriculture, livelihood etc. (City of Tshwane, 2018). Further to this, COMM is currently facing challenges concerning the protection of water resources while ensuring the need to utilize water for beneficial

of the social and economic development is not hindered (City of Tshwane, 2018). Water resources are vulnerable to the effects of climate change and pollution as a result of the resource use (City of Tshwane, 2018). Climate change effects may vary from environment to environment therefore effects on resources will vary as well.

Water resources management within COTMM is a legislated process by the National Water Act (NWA) from National level, sanitation and water supply sitting on local government. In addition to the Acts, there are strategic plans and policies in place for management of water resources within COTMM. Monitoring, assessing and availing information, all forms part of water resources management (Department of Water and Sanitation, 2018). Hennops River basin is situated between Pretoria and Johannesburg. Recently the River has been on the news regarding recent pollution. One of the most shocking events which was reported to Department of Water and Sanitation, took place when the nearby residents noticed the River covered with white foam (Department of Water and Sanitation, 2017). Another incident which precedes this was reported when fish farmers within Hennops River in Northern West of Pretoria had noticed an escalated number of dead fish, which was said to be related to sewage spill into the Hennops River (ENCA news report, 2016).

The Crocodile River basin feeds from Hennops and Juskei River. Currently the Crocodile River basin is highly polluted. It is unknown which amongst the Rivers contributes pollution to the Crocodile River basin. However, it is known that the two Rivers are heavily polluted, but whether or not the management approaches employed are effective in protecting the two Rivers, the answer is unknown. It is furthermore noted that a gap exist in terms of knowledge regarding evaluation of the current management approaches employed in protecting the ever polluted Hennops river. The River side walk always has a pungent smell, with either solid was and sludge visibly present often times. The River is hardly aesthetically appealing in most times when accessed.

The unprecedented changes experienced by the Hennops River remains the news headlines as the regulating authorities appear to be reactive in all incidents. The major problem with this kind of intervention is that it appears as though the government is

poorly managing surface water resources. Such alarming water pollution incidents calls for an intensified regionally appropriate effort/solution when dealing with issues of water quality.

In view of the above discussion, this study ***evaluated the effectiveness of the current water resources management approaches in maintaining the requirements of South African guidelines for aquatic ecosystem for the Hennops River in Gauteng Province.***

1.2.1. RESEARCH QUESTIONS

In light of the above discussion, the following questions guided the research process:

I. What is the current surface water quality status for Hennops River in relation to the South African Water use Quality Guidelines: Aquatic Ecosystems?
II. If any, do the authorized water users of Hennops stream comply with the requirements and conditions set out in the authorization's and how is the compliance monitored and enforced?
III. Are there any unauthorized activities taking place around Hennops River which may pose threat to the water quality of the stream and how does the regulating authorities deal with unauthorized water users?
IV. What are the implications of the findings of this study in a wider context with specific reference to other provinces within South Africa?

1.3. RESEARCH AIM AND OBJECTIVES

The aim of the study was twofold: firstly, to investigate the effectiveness of the current water resources management approaches and institutional framework, as well as, plans and policies applied in ensuring that water resources quality is not impacted upon by both authorized and unauthorized water users. Secondly to ascertain the seasonal variation of water quality within Hennops stream.

In view of the above aims, the objectives were:

I. To identify all institutions and their legal mandate, that play a role in water resource management (and ensuring a legally required water quality standard is achieved and maintained).

II. To identify all authorized and unauthorized water users within Hennops River and management approaches employed in ensuring that water users remain compliant to the water use licenses.

III. To establish the implication of current institutional framework on water resources management and applied approaches.

IV. To establish the current water quality status in terms of the SAWQG:AE and furthermore to contribute knowledge to the body of water resources management particularly in South Africa.

1.4. SUMMARY OF LITERATURE REVIEW

This section provides a summary of literature reviewed, with a detailed account in Chapter Two. The summary consists of contextualized global, African, Sub-Saharan and local perspective on water resources management approaches adapted by various states. This is done in an effort to highlight challenges as well as gaps present in the current water resources management approaches.

Natural resources management has become a global issue with its availability largely dependent on its management. Water as a natural resource covers 71% of the earth's surface and of the said percentage cover, 0.3% is the only percentage available for consumption from Rivers, lakes and atmosphere (Li *et.al.*, 2018). With this small percentage being available for consumption on a global scale, its allocation and management should be properly coordinated. Li *et.al*. (2018) in their article titled "Efficient-equitable ecological evaluation of regional water resource coordination considering both visible and virtual water" noted that the overall evaluation of the coordination of water resources have not sufficiently received consistent evaluation.

Surface water resources are used for various aspects of life, with some surface water resources labelled as “Drinking water catchments” (Almaarofi, 2017). “Drinking water catchments are sites where fresh water is collected and used for drinking water supply purposes” (Almaarofi, 2017). Previous research studies have reported that surface water resources are prone to pollution from point and non-point pollution sources of pollution (Alami et.al, 2018; Almaarofi, 2017).

While pollution, as a global challenge, affects the quality of water within a stream, mitigation measures should enhance water quality, environmental, societal and economic values (Almaarofi, 2017). Government departments across the globe have been compelled to embark on various water resources management programs in an effort to ensure that available water resources are of a quality acceptable for protection of aquatic ecosystems and utilization. The current global water resource management challenges that have been predicted to persist for the next 50 years include climate change, growing urban demand and land use changes (World meteorological organization, 2019). These global challenges have proven difficult in managing based on the current management approaches. The challenges still persist within the existing management approaches

While water stress occurs throughout the world, sub-Saharan Africa has been more afflicted than any other regions. Countries within sub-Saharan Africa has emerged and during the year 2015, United Nations (UN) published the 2030 Agenda for the sustainable development in which the term “Indicator” is described as “A qualitative and timely data which is needed to help with measurement of progress of a specific set goal” (United Nations, 2015). In the past decade, the indicators which were used to measure developmental progress within the continent of Africa in terms of delivering the socio-economic rights consisted of 8 millennium development goals, “Ensuring environmental sustainability” was amongst the goals (Republic of South Africa, 2013). It was then noted that the concept of millennium goal was too vague and took into account all aspects of environmental resources, with water provision and water resources protection encapsulated into environmental protection goals.

In comparison with above global and Sub-Saharan management challenges, recent research studies show that pollution prevention, pollution control and ability of aquatic ecosystems

to deliver ecosystem goods and services are still prominent challenges in the water resources field within South Africa (Ashton and Hardwick, 2008). Gauteng is regarded as the economic hub of the country with citizens of the country migrating mostly from rural areas to Gauteng searching for better living conditions (Tomaschek et.al, 2017). While population increases, natural resources do not increase to cater the needs of the population, thereby rendering the natural resources inversely proportional to the demand, thereby putting stress on the available resources.

Available water resources are to be utilized and cater for all residents. The South African Constitution, chapter three gives effect to three spheres of government namely: National, Provincial and Local (Constitution of the Republic of South Africa, 1996). These spheres, in terms of their structure and functions, they are distinctive, interdependent and interrelated and each have its own mandate. In terms of water resources management, the national government's constitutional mandate is bulk coordination and management of the country's water resources while local government has legislative and water and sanitation service to the communities. Furthermore, the Department of Water and Sanitation is therefore the custodian of water resources management within South Africa.

As indicated above, the South African Water resources management approach is currently at a decentralized ordination. Regional water resources management has allowed participation of water users. The establishment of the Catchment Management Agency, Catchment Management Forums, implementation of water quality monitoring programs and compliance enforcement of water users has all been implemented as management approaches within South Africa.

As noted by Almaarofi (2017) "different frameworks have been developed to evaluate water resources management strategies", however most of recent studies have rather put effort on the evaluation of surface water quality management options in meeting specific water quality standards for a River or catchment. Secondly the overall water resources management approaches employed strongly lack on maintenance of the integrity of aquatic ecosystems. This research intends to expand literature knowledge on water management approaches employed in maintaining the aquatics ecosystem.

1.5. SUMMARY OF METHODOLOGICAL CONSIDERATION

This section introduces the methodology that was employed in evaluating the effectiveness of the current water resource management approaches in maintaining the requirements of the South African guidelines for aquatic Ecosystem within the Hennops River. A detailed account is presented in chapter three.

The study's adopted used both qualitative and quantitative. Data collection tools used were institutional assessment, literature review, interviews and analysis of water quality data from Department of Water and Sanitation (DWS). Residents along the Hennops River in Centurion area and specialists in the field of water resources management were interviewed. A research proposal was presented at the Hennops River forum, which consisted of various organization's representatives and stakeholders. Questionnaires were then handed over to all the Hennops River forum members who were present during the presentation so that they could complete it in their own time, as they had indicated that they needed to rush back to their respective working areas.

In order to corroborate results of the interview, site inspections were conducted along the Hennops River within Centurion area, and photographs were taken as evidence.

Legal requirements along with institutional establishment was also evaluated against the set water resources management legal requirements. Raw water quality data was abstracted from the DWS Water Monitoring System, for point which passes along Centurion area. Analysis and interpretation was then performed and conclusion drawn from the available analyzed water quality data.

1.6. ETHICAL CONSIDERATION

During data collection processes, interviews and questionnaires were used to gather views and knowledge of people. Research where humans will participate as research participants should be based on a ground moral commitment to individuals concerned, and to provide and advanced knowledge and understanding (Ethical considerations, 2013). One of the ethical principles that the study subscribed to was the concept of beneficence whereby the researcher ensured that no harm was inflicted on all research

participants. Compliance to this was ensured through the signing of a consent form by the participant and the researcher. The consent form was developed by the researcher. The research furthermore ensured that participants do so voluntarily and are given right to privacy and all research participants were respected. Before the phase of data collection took place, the researcher ensure that an ethical clearance was obtained from the University of the Witwatersrand. Once cleared, permission was granted by the Councilor to proceed with interviews of community members. The researcher ensured that the purpose of the research was explained to all participants.

Confidentiality is defined as "spoken or written in confidence; charged with secrets" while anonymity is defined as "of known name, of unknown authorship" (Orb *et.al.*, 2006). Research participants were informed of a confidentiality and anonymity principle that will be adhered to during the course of the research. Data will not be shared with a third party without consent of participants and ensuring anonymity. The study ensured compliance with the ethical policy of the University of the Witwatersrand.

1.7. SCOPE OF THE STUDY AND LIMITATIONS

The study was limited to the portion of the Hennops River which passes through Centurion. Region 5 of the jurisdiction of the City of Tshwane includes the portion of the Hennops River that was considered for this study. Institutional assessment data use for the study dates back from the time when the first National Water Act was enacted (1998) till now.

Interviews and questionnaires were only conducted with community members within Centurion area, specialist NGO's involved with Hennops River and some government officials from the Department of Water Affairs, who were willing to participate in the research study. Site inspections were conducted and were limited to the study area and observations were drawn thereon.

CHAPTER TWO

THEORETICAL CONSIDERATION AND LITERATURE REVIEW

2.1. INTRODUCTION

Literature refers to a collection of academic research, usually in the form of articles and books (Fernandez, 2019). Literature review is therefore considered to be findings and reading of multiple papers in an effort to identify and demonstrate ideas that serve as a basis for a thesis in a systematic manner. A literature review forms a vital role in research and aids in the demonstration of knowledge pertaining to the research topic, identification of ideas and development of theory. This chapter is dedicated to a review of the literature; a detailed comparison of other researcher's findings will be presented here. The views, findings and recommendations of other researchers will be considered in the current chapter and acknowledged by means of reference within context and a list of reference at the end of the research report.

Although it would be more informative to reflect on all information that has been written globally on the subject matter, the current literature review present knowledge that the researcher has as per all the literature sources that was consulted.

Firstly, the global perspective on water resources management will be discussed. This is to ensure that the global understanding of water resources management is understood which will thus aid in comparison with the regional and local perspective of water resources management. This will then be followed by the sub-Saharan perspective on water resources management where regional management approaches and challenges are discussed. The same layout will be used for the local perspective i.e. South African perspective on water resources management. Lastly the gaps will be identified as conclusion of the current chapter.

2.2. CONTEXTUALIZING THE LITERATURE: GLOBAL PERSPECTIVES ON WATER RESOURCES MANAGEMENT

Natural resources management has become a global issue with its availability largely dependent on its management. Water covers 71% of the earth's surface and 0.3% from the 71% is available for consumptions from Rivers, lakes and the atmosphere (Li *et.al.*, 2018). With this small percentage being available for consumption on a global scale, its allocation and management should be properly coordinated. Li *et.al*. (2018) in their article titled "Efficient-equitable ecological evaluation of regional water resource coordination considering both visible and virtual water" notes that in terms of overall evaluation and coordination of water resources, efforts have not been much vested in this aspect of water resources management. Throughout this thesis, the phrase "water resources management" is used to refer to the scientific field that assists in a "rational, equitable and efficient way of water resources development, treatment and use, safeguarding the sustainability of water resources and the environment" (Benedin and Tsakirs, 2013).

Surface water resources are used for various aspects of life, with some surface water resources labelled as "Drinking water catchments" (Almaarofi, 2017). The term "drinking water catchments" was used by Almaarofi (2017) to refer to identified areas where fresh water can be collected and used for the supply of human consumption. Previous research studies have reported that surface water resources are prone to pollution as a result of point and non-point pollution (Alami et.al, 2018; Almaarofi, 2017; Meissner *et.al.*, 2018; Tang *et.al.*, 2019). With this in mind, a large and growing body of literature has investigated sources of water pollution, with a remarkable study done in Poland where Szalinska (2017) found that anthropogenic pressures are amongst many other pressures which impacts negatively on the quality of surface water resources. The most prominent anthropogenic pressures are urbanization, deforestation, and destruction of wetlands, industries, mines and agriculture (water wise, 2019). While urbanisation results in the increased use of fertilizers to grow food, this ultimately ends up in water bodies which results in algal bloom (Water wise, 2019). Mines and industries release chemically contaminated water into natural water bodies which results in disturbance of pH and nutrient levels (Water wise, 2019). This finding was supported by Dasgupta *et.al* (2017) who found that wastewater and energy production

impacts the quality of surface water and this type of pollution is an anthropogenic process which in turn forms part of what is called a point source water pollution. The release of Sulphur and Nitrogen during coal burning for energy production results in acid rain which pollutes surface water resources (Water wise). These activities are can either be found conducted as authorized or unauthorized water use activities. One of the research objective was to identify authorized and authorized water user within the research area, it is now evident that even globally such users are found.

While pollution, as a global challenge, affects the quality of water within a stream, mitigation measures should enhance water quality, environmental, societal and economic values (Almaarofi, 2017; Wilson, 2019). Which when put in simple terms refers to water management approaches. Government departments across the globe have been compelled to embark on various water resources management programs in an effort to ensure that available water resources are of a quality acceptable for maintaining aquatic ecosystems.

In 2017 Szalinska published a paper in which he chronologically described development of water management legislation and its changes over the history of Poland. Water legislation, management and research has evolved over time. Currently Poland is amongst the countries which are members of the European Union (Szalinska, 2017). A substantial development within the water management sector came when water licensing, allocation of consumption quotas, taxing irrigation canals & water ways and position of water as source of power generation came into place (Szalinska, 2017). The first water act for Poland was enacted in 1922 with emphasis on water ownership, user rights and pollution prevention by banning of liquids and items relinquishment into water streams since they degrade the quality of water within the streams (Szalinska, 2017). The amendment of the act to the 1962 came with penalties for pollution by state owned companies and prevention of accidental harm to the environment (Szalinska, 2017). Szalinska (2017) furthermore indicated that the 1974 act again neglected reinforcement and measures to control pollution. The recently promulgated Act took place in the year 2011 and improvements as a result of the Act are too early to be visibly noted, however the announced changes are related to management and taxation issues (Szalinska, 2017). In view of all that has been mentioned so far, regarding water management in Poland, it is clear that legislation has not set a profound precedence for a

proper framework of surface water resources management in its previous and current resources management legislation. These legislative development framework, as discussed on a global perspective, will also be discussed in the context of the research area as it serves to answere the research objective (i).

Another highlight in the water management sector took place in India where research conducted by Dasgupta *et.al* (2017) focused on the application of nanotechnology in water quality management. Dasgupta identified various nanotechnology tools which can be used for purification of water such as: Photo catalysis for decomposition of many toxic compounds with the likes of pesticides which, according to Dasgupta, does not degrade easily under normal conditions; Carbon nanotube-desalination; and ligand based nanotechnology - removal of heavy metals and metal oxides. Nanotechnology as a water quality management tool is still growing and under research, however it has its weakness. According to Dasgupta et.al (2017), treated water should still undergo compulsory testing before water can be utilized. This thus reflect weakness in the system and results in increased cost implications.

In a study, which sets out to evaluate overall management while looking into issues of contamination and possible quality evaluation of groundwater at North Cyprus, Arslan and Akun (2018) found that various incidents affect water resources management procedures negatively. One would then be more interested in knowing such incidents. The incidents include leakage of pipes for water transportation, licenses of drilling issued without scientific consideration and poor to non-existence of water licenses for all other water uses (Arslan and Akun, 2018). If these incidents are known, why then are there no procedures in place to deal with these incidents proactively? Water resources management approaches should be sufficient to address known, unknown and foreseeable risk. If all aspects that impact negatively on water quality are known, then they should be addressed from the procedure development perspective which will thus ensure that much of water quality management crisis are not in existence. Guzelyurt is situated within the Cyprus region. Guzelyurt has in place, a water quality management procedure that recognizes the importance of water quality monitoring (WQM) programme (Arslan and Akun, 2018) which has been acknowledged globally as a critical water resources management tool.

WQM refers to "establishment and implementation of operational and compliance WQM programs, including the location of sampling points, sampling frequency and determinands" (South African National Standard, 2015). Arslan and Akun (2018) on their research, took water samples at Guzelyurt for analysis, whereby physiological parameters were analyzed and results reported. Arslan and Akun (2018) notes that there were no other results from the regulating authority to compare their results with. In general, therefore, it seems that the region has well written programs which are not put into action. Management approaches are therefore lagging behind in implementation when compared to written procedure.

As mentioned above, globally water management entails WQM programme whereby specific streams will be sampled for laboratory analysis either chemical, biological or biophysical parameters. Currently many WQM programs are under stress which has thus resulted in financial cuts that has inevitably resulted in forcing water managers to reduce sampling points (Bieroza, 2018). Water managers are therefore faced with critical monitoring point question of: amongst the currently monitored points, which monitoring location should be kept and continue being monitored and which long term time series to continue with? (Bieroza, 2018).

It goes without saying, legislation plays a critical role when dealing with issues of management of surface water resources. Canada is amongst countries which lack behind the water management legislation. Yukon First Nations is one of the communities within Canada that suffers the impact of none codified indigenous legal traditions which is currently used to govern water issues (Wilson, 2019). The Yukon community is currently on process of implementing self-government and modern land claim procedure which includes the right to unaltered water quality, quantity and rate of flow (Wilson, 2019). Implementation of self-governing procedure will definitely present gaps in terms of water quality management, which could be closed had it been a state governing project that would be well funded, consist of scientists and legal experts who would drive this development. This thus provides an indication that globally water management approaches are still lagging behind and thus result in affecting the status of water quality. Knowledge regarding the effects of poorly

coordinated water quality management structure in Canada has not been exhausted whereby proper recommendations to close the gaps would be in the implementation phase.

Interestingly, Canada does issue out water use authorisations in terms of land and resources Act, 2012 with conditions that monitoring and reporting of water quality data in the interest of protecting quality, quantity and rate of flow of water should be reported to the regulating authorities (Wilson, 2019). The questions remain: Is this sufficient in terms of water quality management? Does the state not see the need to monitor compliance with the authorisations from the states perspective and not the water users themselves? Is the monitoring and reporting to the regulating authority sufficient enough to ensure pollution, misuse and water quality deterioration are avoided? Such questions will thus remain unanswered until such time that the Canadian government closely look into adopting water quality management systems of other countries which are doing better in terms of water quality management. The inconsistency of the results will not be fully identified and compared with the ones from the regulating authourites.

Globally water management challenges vary from area to area, more so depending on the type of use and pollutants of that particular stream. However, water quality management tools employed to a specific stream can counteract the effects of deterioration of water quality. Another study conducted at the United Kingdom whereby the concentration discharge slope was used as a water quality management tool to a highly agriculturally managed water quality stream. Determinates such as Phosphates, Nitrates and Suspended solids were considered in the study (Bieroza et.al, 2018). The determinads were monitored in both high frequency and long term low frequency monitoring (Bieroza et.al, 2018). The high frequency data sets comprised of water samples taken on an hourly and sub-hourly basis for naturally flowing stream and one where water was pumped into a hut with the long term low frequency entailing monthly water samples taken from the stream (Bieroza et.al, 2018). The samples were taken from varying streams i.e. streams from different countries (UK Norway and Sweden which are the EU countries). All the streams were agricultural streams which were subjected to risk of eutrophication monitored fortnightly, Sweden and six to twelve times a year for UK Norway (Bieroza et.al, 2018). The results showed

predominant for both datasets in terms of concentration discharge relationship. In terms of low frequency datasets, the mean concentration varied between determinands and countries (Bieroza et.al, 2018). The results when interpreted in simple terms shows that catchments have a tendency of transporting and storing pollutants and therefore should be monitored to allow further intervention by water managers (Bieroza et.al, 2018). In the study, Bieroza et.al (2018) recommended the concentration discharge frequency as a tool to WQM as it is capable of capturing accurate estimates of water quality parameters for low frequency sampling. Although the concentration discharge can be used on an already existing data sets, the shortcoming of the study remains lack of incorporation of costs associated with the application of concentration discharge relationship during the current tough financial status. This thus provide further proof that water quality management tools which are in place for managing countries across the globe comes across as being effective while in reality they present gaps for improvement.

Various tools exist in place for surface water management ranging from plans, policies to modelling. “A water quality model can mean anything from a single empirical relationship through a mass balance equation, to a complex software equipment’s” (Cox, 2013, quoted by Benedini and Tsakiris, 2013). A recent water quality model research was conducted by Tang et.al (2019) at Australia. The research focused on closing the global, basin and local scale water quality modelling towards coming with measure that will enhance water quality management. Tang et.al (2019) reviewed the literature around water quality modeling and found that modeling for surface water resources is applied from varying scales, ranging from individual field stream to global and dates back to 1920’s. Tang et.al (2013) pointed that globally, water quality models should be subjected to sufficient consideration on a basin/local scale and that global water quality models are rarely considered in water related policy making or water management. Therefore, one would suggest the need for implementation at a regional level so as to ensure that water managers familiarizes themselves with the processes involved in water modeling prior to being part of the global projects. When we look onto the asin/local scale models, these models provide more detailed assessments of water quality issues, based on better local data and the fact that it is based in an area where issues need to be managed at (Tang et.al, 2019).

The main issues identified globally are the challenges pertaining to financial availability for WQM, the need to re-structure institutions which are currently mandated with the duty of water resources management and amendments of existing legal legislative requirement. All these forms an integral part of surface water resources management.

2.3. CONTEXTUALIZING THE LITERATURE: A SUB-SAHARAN AFRICAN PERSPECTIVE ON WATER RESOURCES MANAGEMENT

In the history of water resources management within the region, water quality has been thought of as a key factor in the provision of safe drinking water. Unevenly distributed water resources has thus resulted in an inadequate access to sufficient and clean drinking water has been identified as the cause of death and many reported cases of diarrheal disease (Classen et.al, 2014 quoted by Kayser et.al, 2015). Kayser et.al (2015) shows how, in the past, research in water resources management, involved only technological advances to improve protection of water resources and treatment of water, but lacks in terms of ability to deliver safe drinking water overtime.

In terms of drinking water quality, the management of this aspect of water management varies from country to country. Malawi is amongst many sub-Saharan African countries which have suffered adverse effects of poor water quality. In a research conducted by Kayser et.al (2015) where the study focused on drinking water quality governance, while comparing three countries namely Brazil, Ecuador and Malawi, the Ministry of irrigation and water development and the National water resources board were identified as the responsible national government departments for drinking water quality governance. In view of this, Malawi does not have a single department which is a custodian of drinking water quality, therefore this creates a problem whereby one department can shift blame when dealing with failures pertaining to water quality, unless if their mandates does not overlap between the two departments. Kayser et.al (2015) made several findings for the three mentioned countries however there were four common ones. The four common findings were: insufficient coordination and sharing of water management data amongst ministries, followed by inadequate monitoring, enforcement and consistent water quality laws, insufficient technical capacity for water quality testing in rural areas and last one being

scarce financial resources. These common findings further support the idea that the current water resources management approaches are not effective in maintaining the legally required water quality in countries where water quality is legislated.

Countries within the Sub-Saharan has emerged and during the year 2015, United Nation (UN) published the 2030 Agenda for the sustainable development in which the term "Indicator" is described as "A qualitative and timely data which is needed to help with measurement of progress of a specific set goal" (United Nations, 2015). In the past decade, the indicators which were used to measure developmental progress within the continent of Africa in terms of delivering the socio-economic rights consisted of 8 millennium development goals, "Ensuring environmental sustainability" was amongst the goals (World Bank Group, 2013). It was then noted that the concept of millennium goal was too vague and took into account all aspects of environmental resources, with water provision and water resources protection encapsulated into environmental protection goal.

In a report for transitioning from the millennium development goals to sustainable development goals, World Bank group (2013) reported that access to safe drinking water was amongst important aspects which were used to measure and monitor progress and target was achieved in some countries ahead of 2015. It was then noted that the sub-Saharan African countries lags far behind regions known to be developing on most targets, apart from progress made on water scarcity, the water scarcity has been projected to worsen thereby being furthermore scarce (Millennium Development Goals report 2015, 2015). Further engagements were made in review of millennium development goals and the agreement reached was to end the millennium development goals at the end of the year 2015 which was then succeeded by the sustainable development goals running until the year 2030 (PMC, 2015). It is therefore too early to have notable progress made in terms of achieving the sustainable development goals.

A large part of the Sub-Saharan regions relies on surface water resources for livelihood, with the fewer countries, mostly the ones dominated by rural areas, being more reliant on groundwater supplies (Hughes, 2019). Meanwhile, in terms of the management framework for Ghana, of drinking water quality, addresses the prominence of private water vendors

only in terms of raising questions about safety and efficiency of various delivery (Yates and Harries, 2018). Increased water demand places stress on water resources in terms of availability of water from such resources. In some regions, this has thus awakened the regulating authorities to seek, develop and implement measures to counteract these foreseeable impacts. Therefore, the developments were then transferred to consultants which were not from the region, which were not keen to develop local capacity and ultimately the end result was that there was not positive contribution to the sustainability concept for future water management (Hughes, 2019). However, this trend is currently slowly fading away and it is evident within the Southern parts of the region where there is more engagement with other regions merely for sharing and exchanging of technical information and opportunities.

The region is characterized by poor adequate water management information ranging from water quality data to available water resources for present and future water needs (Hughes, 2019). This thus play a major role in objectives of water management policies realization. Hughes (2019) then argued that any thoroughly developed water management policy could not be implemented if it is not coupled by adequate explanatory information. Despite these water management challenges, the residents are still to be served with water of good quality.

2.4. CONTEXTUALIZING THE LITERATURE: A SOUTH AFRICAN PERSPECTIVE ON WATER RESOURCES MANAGEMENT

South Africn surface water resources have been in the news bulletin for all wrong reasons since the late 2015 (World Wildlife Fund report, 2016) with the country known to be a water stressed country amongst the African countries (Naster and Ramasar, 2011). Surface water resources within South Africa are not only used for consumption but for other activities such as recreational, agricultural and mining activities and importantly so the maintenance of aquatic ecosystems (Nthunya *et.al*, 2018). Some of the listed activities introduces a range of pollutants to water bodies (Nthunya *et.al*, 2018).

With that in mind, South Africa is known for its constitutional rights that recognizes both protection of the environment (aquatic ecosystem) and basic human right to water (Yates

and Harris, 2018). Therefore, this triggers a need for "a regular supply of safe, accessible and affordable drinking water and sanitation services of good quality and sufficient quantity" (United Nations General Assembly, 2010 p.3, Quoted by Yates and Harris, 2018). A well formulated water quality management approach is thus a requirement to address these pointers.

South Africa has provinces with a notably growing research interest in the water resources management field. Rural areas have in the past been targeted more in terms water resources management, water quality management precisely so. The constitution of the republic of South Africa (1996), chapter three gives effect to three spheres of government namely: National, Provincial and Local. These spheres of government are distinctive, interdependent and interrelated and each have its own mandate. In terms of water resources management, the national government constitutional mandate is bulk management of the country's water resources while local government has legislative and water and sanitation service to the communities (South Africa, 1996; Meissner *et.al*, 2018). Furthermore, the Department of Water and Sanitation (1996) is therefore the custodian of water resources management within South Africa. In view of these legal mandate, one would then question if these government spheres are doing their utmost best to ensure that available water meets the growing demand? In addition, is the status of the quality of water from available surface water resources within the requirement of the SWQG: AE which will thus ensure the protection of the aquatic ecosystem? Tang et.al (2019) noted that water demand has risen considerably in the past decades due to population and economic growth. The growing water demand places enormous stress on water security of the country.

Water quality management forms a major part of water resources management. "In South Africa, water quality management has evolved overtime from a pollution control approach that focused on the enforcement of uniform effluent standard (Department of water and sanitation, 2016). There are wide range water quality issues within South Africa, varying markedly from stream to stream, impacted upon by different sources of pollution. Bellow, Figure 2.1, is a list of water quality issues. The issues are ranked in terms of high to low impact within the South African context.

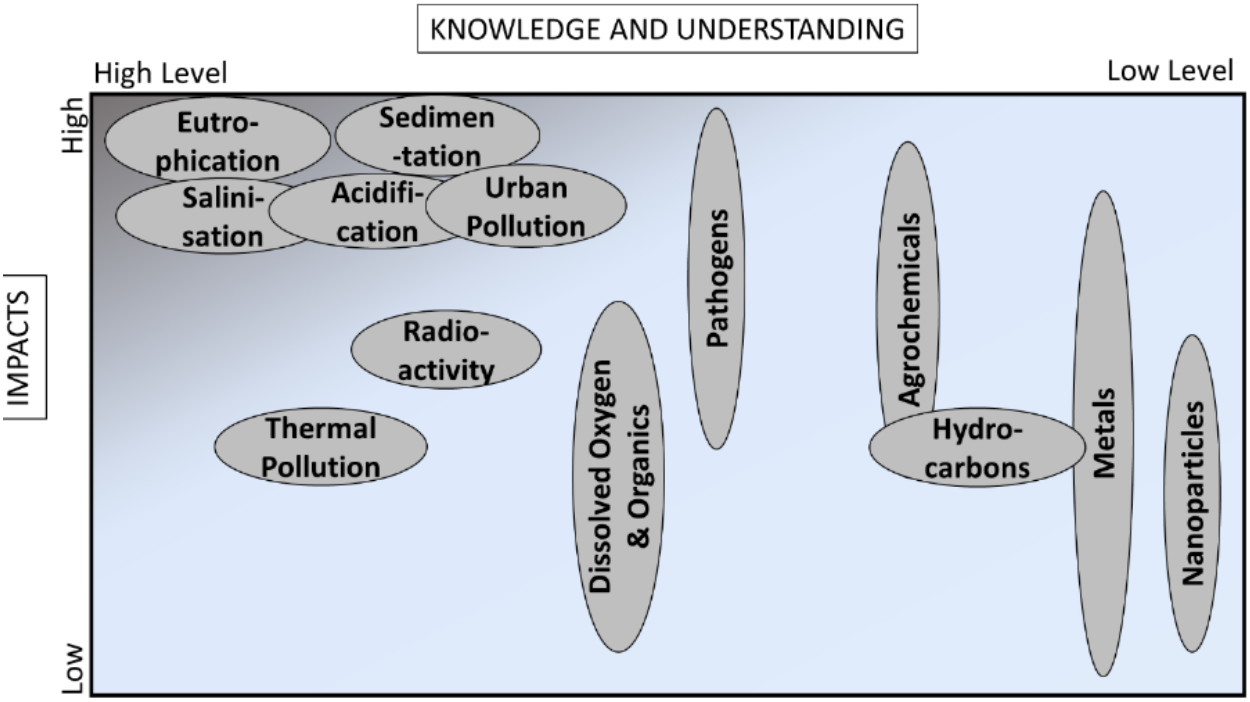

Figure 2.1: List of water quality impacts (Department of water and sanitation, 2016)

As presented in figure 2.1, the five highest impacts are Eutrophication, Sedimentation, Salinisation, Acidification and urban pollution (Department of water and sanitation, 2016). Furthermore, these five high impacts are said to be priority issues. Despite the high impact water quality issues, there are foreseeable trends which have been noted to have potential to grow in the next few decades which could lead to accelerated water quality challenges in many locations across the country. These are climate change, hydraulic fracturing, renewable energy, water energy-food-nexus, growth of inadequately serviced densely populated settlements, water re-use (Department of Water and Sanitation, 2016). To list a few, the primary potential water quality impacts as a result of the said trends, are:

I. Less dilution of water quality constituents;
II. Contamination of surface water resources and groundwater through spillages and leak of chemicals;
III. Impacts of temperature and DO;
IV. Low food or crop yield;
V. Increased pathogens such as *E.Coli*; and

VI. Sludge disposal to be undertaken with minimal risk to surface water and ground water near disposal (Department of water and sanitation, 2016).

Primary drivers	**Root causes**
Eutrophication	
Municipal sewage discharge and overflows	Lack of proper institutional arrangement, sufficient financial allocation, technical capacity in many municipalities along with political reasons.
Diffuse nutrient loadings from cultivated land	The use or applying irrelevant fertilizers, tillage and land management practices.
Acidification and acid mine drainage	
Discharge of acidified groundwater from mines	Historic and failure to incooperate precautionary measures during the planning phase, regulation and enforcement.
Contaminated seepage, runoff and spills mines and coal-fired power stations	Lack of compliance with licence conditions, inappropriate licence conditions, inadequate enforcement capacity.
Wash off and leaching of acidic atmospheric deposits stemming from smoke-stack emission	Issued licenses not being complied to with inappropriate license conditions and lack of enforcement capacity

Salinsation	
Diffuse drainage and wash off of rainfall mobilized natural salts in dryland-cultivated soils, as well as diffuse sub-surface irrigation return flows	Inappropriate dryland tillage and crops, over irrigation, irrelevant technology used for irrigation, lack of intercepting drains leading to evaporation ponds.

Table 2.1: Primary drivers and root causes of the priority water quality issues (Department of water and Sanitation, 2016)

It should be noted that "Poor cooperative governance and inadequate cross regulatory interfaces with DWS "was found to be the root cause of all the primary drivers listed above (Department of Water and Sanitation, 2016). One of the research objective was to identify the authorized and unauthorised water users of the research area. From table 2.1 above, the primary drivers are water users which are impacting the water resources. When one looks into the root cause of the identified primary drivers of poor surface water quality within South Africa, figure 2.2 "Poor cooperative governance and inadequate cross regulatory interfaces with Department of water and sanitation" (Department of Water and Sanitation, 2016) appears as a root cause for all primary drivers. Another notable root cause is the "inadequate implementation of best management land use practices and a notable degree of dysfunction in relevant municipalities" (Department of Water and Sanitation, 2016). To a certain degree, the current water resources management system is proving to be ineffective in alleviating challenges pertaining to the primary drivers of priority water quality issues. It should be noted that these challenges are not different to the ones discussed on the global contextualization of literature.

As noted above that research under the field of water management has grown in rural areas, an interesting and most recent research study was conducted at Limpopo Province focusing on the quantitative analysis of Phenols and PAH's in the Nandoni Dam. The dam has been said to be a government water scheme intended for domestic, irrigation and forestry use

(Nthunya et.al, 2018). The study was a preliminary assessment for dam water quality. Water quality analysis were carried out for various chemical analysis including DOC, TOC, Phenols and PAH's (Nthunya et.al, 2018). The result showed possible introduction of phenols and PAH's into the Dam, with concentration differing in all seasons. Nthunya et.al (2018) concluded that water from the stream is not safe for direct drinking yet people drink the water directly. Nthunya et.a (2018) made a generic recommendation that activities taking place nearby the dam should be monitored in an effort to avoid contamination. Although the generic recommendation will somehow aid in alleviation of water quality issues within Nandoni dam, there are still many other water quality issues which will remain unaddressed that requires proper water quality management system to be in place. This include but not limited to eutrophication, sedimentation and agrochemical pollution, although they have not yet been reported as an issue but are known to be potentially harmful. This is as a result of non-existing to inadequate WQM programme, to which their geographical prevalence is not known. Furthermore, the study did not consider nor made mention of any WQM programs in place by either municipality or the national government. A comparison as well was not drawn between the researcher's water quality analysis results and that of the regulating authority. Even though it is agreed with the finding of the research, evidence of management side of the dam by the regulating authority was not presented, the effects of poor management would've been highlighted. A gap still exists in terms of the effects of poor surface water resources management on water quality.

In terms of improvement regarding WQM within the Republic of South Africa, various forces lead to improvement. The notable one being the global market forces (Knuppe and Meissner, 2016). Knuppe and Meisnner (2016) highlighted that these forces are still not dominating and prioritized on the political water and land management agendas. The Olifants Doorn water management area is monitored and reviewed on a regular basis in light of international standard (Knuppe and Meissner, 2016). Knuppe and Meissner (2016) found water monitoring of Olifants Doorn water management area to have improved. This was done in an effort to ensure that export standards for agricultural industry are met. One would then conclude that the country is in a position to be able to fulfill the legal obligation of managing surface water resources and ensuring that the quality of water within the resource

is compliant. However, this does not take away the fact that there are still many surface water resources which are non to poorly managed, with of course results being poor water quality.

Amongst the nine provinces in South Africa, Gauteng is regarded as the economic hub of the country with citizens of the country migrating mostly from rural areas to Gauteng in search of better living conditions (Tomaschek et.al, 2017). While population increases, natural resources does not increase to meet the needs of the population, thereby rendering the natural resources inversely proportional to the demand and putting stress on the available resources. Available water resources are to be utilized and cater for all residents. As indicated under chapter one, Gauteng province is the smallest province in South Africa which is divided into three metropolitan municipalities VIZ: COTMM, COJMM and EMM with Ekurhuleni further divided into district and several local municipalities (general overview of Gauteng, 2019). Pretoria is situated within the northern part of Gauteng province and is regarded as the national capital city of the Country.

Areas within COTMM are divided into seven regions. The division came into effect when COTMM approved macro structure was effected (Welcome to City of Tshwane, 2015). The aim, as noted on the City of Tshwane website, is "to bring government and services closer to the people and improve service delivery" (Welcome to City of Tshwane, 2015). The city has sixteen department where Utility services department is amongst the sixteen department and is further divided into two departments namely: 1) Electricity and 2) Water and Sanitation, where the latter is responsible to fulfil the provision, water supply and sanitation as the City's sub-division mission (Welcome to City of Tshwane, 2015). This thus speaks to the local government constitutional mandate as indicated in the introductory sub-section.

Centurion is an area within City of Tshwane that fall under Region 5 and is characterized by clean surface water with Hennops River passing through the area (Massive Sewage Pollution Turned Hennops, 2018). Hennops River has a history of clean water, however recently it has caught the attention of news with pollution. A passage in the news bulletin titled "Massive sewage pollution tides have turned the Hennops River, once Gauteng's cleanest River" caught the attention of many citizens within the Gauteng Province (Massive Sewage Pollution Turned Hennops, 2018). Snyman on the news report titled massive sewage pollution, further

added that Hennops River ran pitch black for six months and notes “Healing Hennops River, the River of feces, is a battle against the evil sludge coating the River caused by failing wastewater treatment works and continual sewage spills from broken municipal infrastructure”. Could this be due to poor water resources management systems? Most researcher and news reports lack information pertaining to water resources management systems in maintaining the legally required water quality standard within the Hennops River.

2.4.1. INSTITUTIONAL ASSESSMENT: SOUTH AFRICAN CONTEXT

Literature regarding the South African institutional framework for water management is summarized under this subsection and it will be referred to throughout the remaining chapters. This section also provides relevant theoretical information relating to research object (i) and (iii). Institutional framework and associated legal requirements are presented in this sub-section.

2.4.1.1. LEGISLATIVE DEVELOPMENT: THE NATIONAL WATER ACT NO.36 of 1998

Prior to promulgation of the 1996 Constitution of the Republic of South Africa (1996), there was Environmental Conservation Act no.100 of 1982 (Republic of South Africa, 1982) which was amended in 1983 and then succeeded by the amended 1989 act. This Act was regulated by the then Department of Environment Affairs (DEA). The Constitution of the Republic of South Africa (1996) is the supreme law of the Country and sets precedence for all other legislative development. The current Constitution was promulgated in December 1996 and came into effect in 1997 (South Africa, 1997). Subsection 9 of section 25 under Chapter 2 of the Constitution makes provision for development of legislative and other measures to be taken by the state so as to ensure water and related reforms are in place to continually lead the process of redressing the results of the racial discrimination that took place in the past (South Africa, 1997).

2.4.1.2. The preamble: National Water Act no.36 of 1996

The Preamble of the National Water Act no. 36 of 1996 (NWA) is a slightly longer list. The first four recognizes four critical aspect in water resources management being water as a scarce and unevenly distributed national resource that the water is a national resource and ultimately the aim of water resources management is to achieve sustainability and lastly the protection of quality of water resources is necessary to ensure sustainability (South Africa, 1996). The last part is the acknowledgement of the National government role as the custodian of water resources. The Department of Water and Sanitation (DWS) is a National sphere and the custodian of water resources. Consistence with the Constitutional mandate is noted, as set out in Chapter three of the Constitution.

2.4.1.3. Chapter 2 and 3: National Water Act no.36 of 1996

This chapter requires that the Minister of DWS, hereinafter referred to as the Minister, should develop and implement the National Water Resources Strategy (NWRS) and Catchment Management Strategy (CMS) (South Africa, 1998). The first edition of NWRS was implemented during the year 2004. Hennops River is a tributary that feeds the Crocodile River, which is under the proposed Limpopo North Catchment Management Agency. It was found that an approved Catchment Management Agency (CMA) should develop a CMS.

Chapter 3 requires that the Minister of DWS should classifying water resources and quality objective. Furthermore, the chapter is deemed as the first step of water resources protection and it also mandates the minster to ensure pollution prevention and planning for emergency incidents (South Africa, 1998). The Minister has gazetted the resources classes and quality objective for the Crocodile (West) and Marico in October 2019.

2.4.1.4. Chapter 4: National Water Act no.36 of 1996

There are eleven water use activities which are regulated under Section 21, the general authorization and existing lawful water use under section 22 (South Africa, 1998).

2.4.1.5. Chapter 6: National Water Act no.36 of 1996

In areas where a CMA is not yet established or has been established but due to various reasons, it is not yet operational, all powers and duties of CMA are vested in Minister.

2.4.1.6. Chapter 7: National Water Act no.36 of 1996

Community awareness is amongst the five functions of a Catchment Management Agency (South Africa, 1998). CMA are funded by money, which has been allocated by parliament, from water use amounts charged for water use and money obtained from any lawful source (South Africa, 1998).

2.4.1.7. Chapter 14: National Water Act no.36 of 1996

Chapter 14 makes provision for various National Monitoring System. The provision of data to access the use, quality, rehabilitation of water resources and compliance with resource quality is amongst the national Monitoring system. The chapter also mandates the Minister to keep register of water use authorisations .

2.4.1.8. CHAPTER 16: NATIONAL WATER ACT NO.36 OF 1996

Chapter 16 makes provision for activities which are regarded as offence and remedial action (South Africa, 1998). The IOL News Report (2019) reported on the evidence of one of the WWTP that discharge water into Hennops River. On the news publication, it was found that ERWAT had capacity issues and was for the past year releasing water that is below quality (IOL News report, 2019). Another challenge raised by Snyman (Quoted on the IOL News Report, 2019) was a white foam from one of the outlet pipe. A directive was issued by DWS against this pollution emanating from the Waste Water Treatment Plant (WWTP).

Despite all the above discussed legal requirement and progress made thus far in an effort to comply with the set legal principles, there are best practice methods which are in place to compliment the legal requirements. Blues drop and green drop programme are amongst the best practice methods which DWS has implemented since the years 2008.

2.4.2. OTHER LEGAL REQUIREMENTS

The other legislative requirements are: National Environmental Management Act no.108 of 1998 and the Water Service Act no.108 of 1997. The National Water Act and the Water Service Act compliments each other.

2.4.2.1. THE NATIONAL ENVIRONMENTAL MANAGEMENT ACT NO.107 OF 1998

Focus will now be shifted to the last part of the legislative framework development where a highlight is the National Environmental Management Act no.108 of 1998 (South Africa, 1998) (NEMA). NEMA is more focused on integration of good environmental management into all development activities. Although the Act is more on protection of the environment during developmental stages, with water resources protection being part of the two sections within the Act that are more relatable to the research study. Section 24N mandates the developer to include measures relating to alleviation of damage, pollution, pumping and treatment of polluted or extraneous water (South Africa, 1998). The section furthermore holds the person with whom the Environmental Authorization was allocated to, with the responsibility to protect water resources and mitigate any impacts thereof.

2.5. INSTITUTIONAL FRAME WORK

2.5.1. INTRODUCTION

Management and coordination of water quality for surface water resources has been vested to the Minister of DWS, however other National departments, including provincial and local play a role in water quality management. Establishment of water management institutions and departments are guided by section 2.4.1.

2.5.2 SUMMARY OF WATER MANAGEMENT INSTITUTIONS

National Sphere	Provincial Sphere	Local Sphere
I. First tier: The custodian of water resources	There is no provincial sphere of government, however functions of	Within the study area, the local sphere is COTMM.

The minister of DWS II. Second tier: **CMA and CMS** The establishment of Crocodile CMA, to which Hennops River falls under, awaits approval by the Minister of DWS. III. Third tier: **Water User associations**	provincial sphere of government are performed by DWS's provincial office.	

Table 2.2: Spheres of Government responsible for surface water resources management

Within the study area it was found that there are no water user association due to the fact that the study area is within Urban area where surface water resources are not subjected to water use for irrigation.

2.6. SUMMARY: WATER MANAGEMENT APPROACHES IN PLACE

The NWA is a piece of legislation that guides management approaches of the South African water resources.

2.6.1. WATER MANAGEMENT AREAS IN SOUTH AFRICA

Water Management Areas (WMA) were previously 19 in total. The Institutional Reform and Realignment (IRR) process brought about changes in the total number of water management areas. In November 2016, the Minister of DWS published the new 9 water management areas of South Africa (South Africa, 2016). The list comprised (South Africa, 2016):

I. Limpopo WMA;
II. Olifants WMA;
III. Inkomati-Usuthu WMA
IV. Ponola-Mtamvuna WMA;
V. Vaal major WMA;

VI. Orange WMA;

VII. Mzimvubu-Tsitsikamma WMA; and

VIII. Breed-Gouritz WMA; and Berg-Olifants WMA.

Figure below shows demarcation of the 9 water management areas.

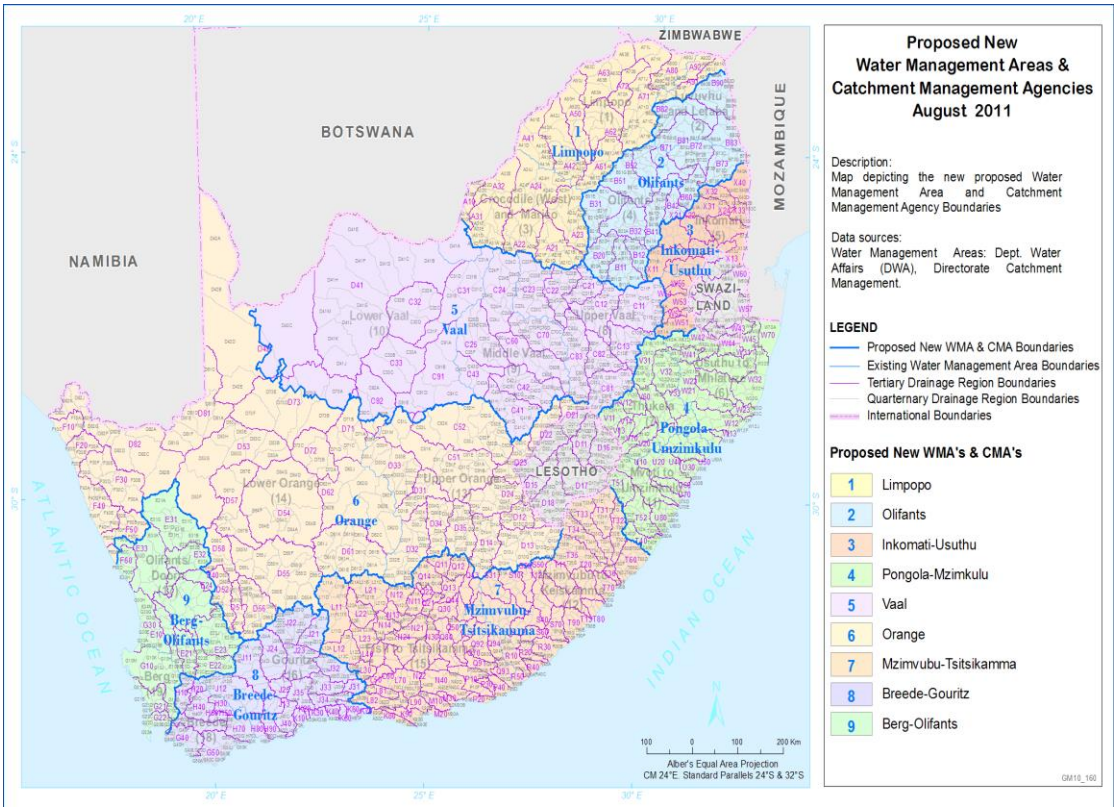

Figure 2.2: The nine new water management areas

Limpopo water management area comprises two former water management areas:

I. The crocodile west and Marico WMA; and

II. The Limpopo WMA.

The Hennops River system form part of the new Limpopo WMA, however currently water management data of the study area is still packaged under the old WMA being the Crocodile west and Marico.

2.6.2. CATCHMENT MANAGEMENT AGENCIES

Limpopo North West Catchment Management agency has only been established on paper for Limpopo WMA (Greengazzett, 2014). The CMA is still not yet operational and therefore its duties are carried out by the DWS. The role of CMA is to assist in ensuring that surface water resources are managed in accordance with the national polices, guidelines and standards in their jurisdiction, through active participation of local communities and other stakeholders in the water resources (South Africa, 2013).

2.6.3. WATER MANAGEMENT STRATEGIES

Chapter 2 of NWA requires the establishment and implementation of (South Africa, 1998);

I. The NWRS; and
II. The CMS.

2.6.3.1. THE NWRS

The NWRS is a strategic document that "provides the framework for the protection, use, development, conservation, management and control of water resources for the country as a whole" (South Africa, 1998). The NWRS revision 2 was promulgated in the year 2013. The purpose of the NWRS is the (South Africa, 2013):

I. Facilitation of proper management of nations water resources;
II. Provision of framework for the protection, use, development, conservation, management and control of water resources;
III. Provision of framework within which water will be managed at a regional or catchment;
IV. Provision of information about all aspects of water resource management; and
V. Identification of water related developments opportunities and constraints.

2.6.3.2. THE CATCHMENT MANAGEMENT STRATEGY

The NWS require that the CMA develops and implement a CMS (South Africa, 1998). A CMS is defined as a framework for water resources management in a water management area

(Groundwater dictionary, 2019). The CMS is a statutory document developed by a CMA and is regarded as a statutory document which provides the vision and the strategic actions to address water resource management issues and its framework is guided by the NWRS (groundwater dictionary, 2019).

In terms of the Limpopo North West CMA under 4.3.2, currently the CMA duties are executed by DWS.

2.6.4. RESOURCE DIRECTED MEASURES FOR PROTECTION OF WATER RESOURCES

The integrated manual is a manual that was developed to address all resource directed measures (South Africa, 1999). This integrated manual came with a new and broader definition of a water resource: "A water resources is an ecosystem which includes the physical or structural aquatic habitats, both instream and riparian, the water the aquatic biota and the physical, chemical and ecological processes which link habits, water and biota" (South Africa, 1999). The integrated manual also brought changes from water quality to resource quality (South Africa, 1999).

The resource directed measure for the resource quality objective requires, amongst others the requirement for water quality should be set in alignment with the current guidelines and procedures as set out in the South African Water Quality Guidelines (South Africa, 1999). In respect of the study area, water resource classes and resources quality objective has not been determined for the Limpopo WMA and the established Limpopo North West CMA.

2.7. GAPS IN KNOWLEDGE

In view of above contextualized literature, the following can be said. Firstly, water resources on a global scale has experienced similar impacts, with anthropogenic pollution noted as a prominent cause of water quality deterioration. Secondly the water quality monitoring programme is a water resources management tool amongst many other management approaches, however research within water resources management field has recently focused on advancing the water quality monitoring programs. Lastly the water quality

monitoring programs are facing financial cuts, and as a result most of the sub-Saharan and countries have resorted to cutting various monitoring points, more so within the local regions.

It is acknowledged globally and regionally that water resources should provide social and economic benefits therefore its proper management is of dire importance. There is no literature that seeks to evaluate the effectiveness of the currently employed management approaches in meeting the regionally appropriate WRM guidelines. This study will therefor use the SAWG: AE to evaluate the effectiveness of the current WRM approaches in managing Hennops River system in South Africa.

CHAPTER THREE

METHODOLOGICAL CONSIDERATION

3.1. INTRODUCTION

When conducting a research there are various steps, which should be adhered to in order for a study to achieve the desired outcomes. The study aimed to evaluate the effectiveness of the current water resource management approaches in achieving the requirements of the SAWQG: AE for Hennop's River. In this chapter, the research positionality and sources of data that were referred to during data collection are discussed. The relevance of the chosen research positionality and sources of data will be highlighted. The first section of the current chapter will be dedicated to describing the research positionality while the second section outlines the sources of data that was consulted during the study.

3.2. RESEARCH POSITIONALITY

According to England (1994: 82) "..research is a process not just a product" as cited by Ratnam (2019). Often times a researcher is concerned with the product of the research instead of the actual research process. There are various steps, which should be adhered to in order for a researcher to achieve the desired outcomes. It is necessary here to clarify what research is. Research is defined as "a systematic search for pertinent information on a specific topi"c (Kothari, 2004). Academics, scientists precisely so, have an inquisitive instinct when confronted with unknown, this thus result in initiation for search of answers.

3.2.1. RESEARCH METHODOLOGY

Research evaluation is defined as a process of measuring the effectiveness of certain selected programs and/or aspects in delivering specific set outcomes (Rutman, 1980:17, reference by Safe, 2016). Although difference of opinions still exists, there appears to be some agreement that evaluation research is an example of applied research whereby a researcher would seek to evaluate the impact of specific intervention, method and innovation in service delivery (Kothari, 2004). Kothari (2004) notes that despite having variously identified and described types of research, there are two basic approaches to research, which is qualitative approach and quantitative approach. In terms of the type of approach that is to be employed

for a research, such decisions lie upon a researcher and it is also informed by which approach is more suitable to the intended research (Kothari, 2004). Kothari (2004) described qualitative approach as a research that is mainly focused on the assessment of attitude, opinions and behavior, while quantitative approach is more into the data generation using the quantitative form, which then is subjected to rigorous quantitative analysis in a formal and rigid fashion.

Multi-methodology as a concept has been defined by Mingers (2001:289, quoted by Watkins, 2004), as being a process of combining together more than one methodology, in whole or part, within a particular intervention. For this research the predominant adopted were both qualitative and quantitative.

3.3. DESCRIPTION OF THE RESEARCH SITE

South Africa is situated predominantly in parts of the African continent which are referred to as "semi-arid" associated with spatial distribution of rainfall (DWS, 2004). Water availability across the country is highly uneven (DWS, 2004) and therefore a well-structured management approach is of dire importance (Tantoh and Simatele, 2018). Gauteng is the province, which has seen great economic enhancement and therefore referred to as the economic hub of South Africa (Tomaschek et.al, 2015) with City of Tshwane as a capital city of the country (City of Tshwane, 2018). Hennops River system was studied, mainly parts of the River in Centurion area. This is articulated to the pollution incidents, which the area has experienced in recent years, with continual experience of the effects of the said pollution.

Hennops and Jukskei Rivers converges to form the crocodile River basin (refer to figure 3.1) which forms part of the Limpopo water management area. Jukskei River falls under the jurisdiction of CJMM and EMM whilst Hennops River is under the jurisdiction of City of Tshwane Metropolitan Municipality. Furthermore, the study area, as per the CTMM structure, is managed also from a regional point as per Region 4: Regional Integrated Development Plan (2014). Within the study area, Hennops River catchment management forum has been established with meetings held. From the catchment management forum meeting, it is still not known which of the River system i.e. either Juskei or Hennops River, is the one contributing more of pollution into the Crocodile River basin.

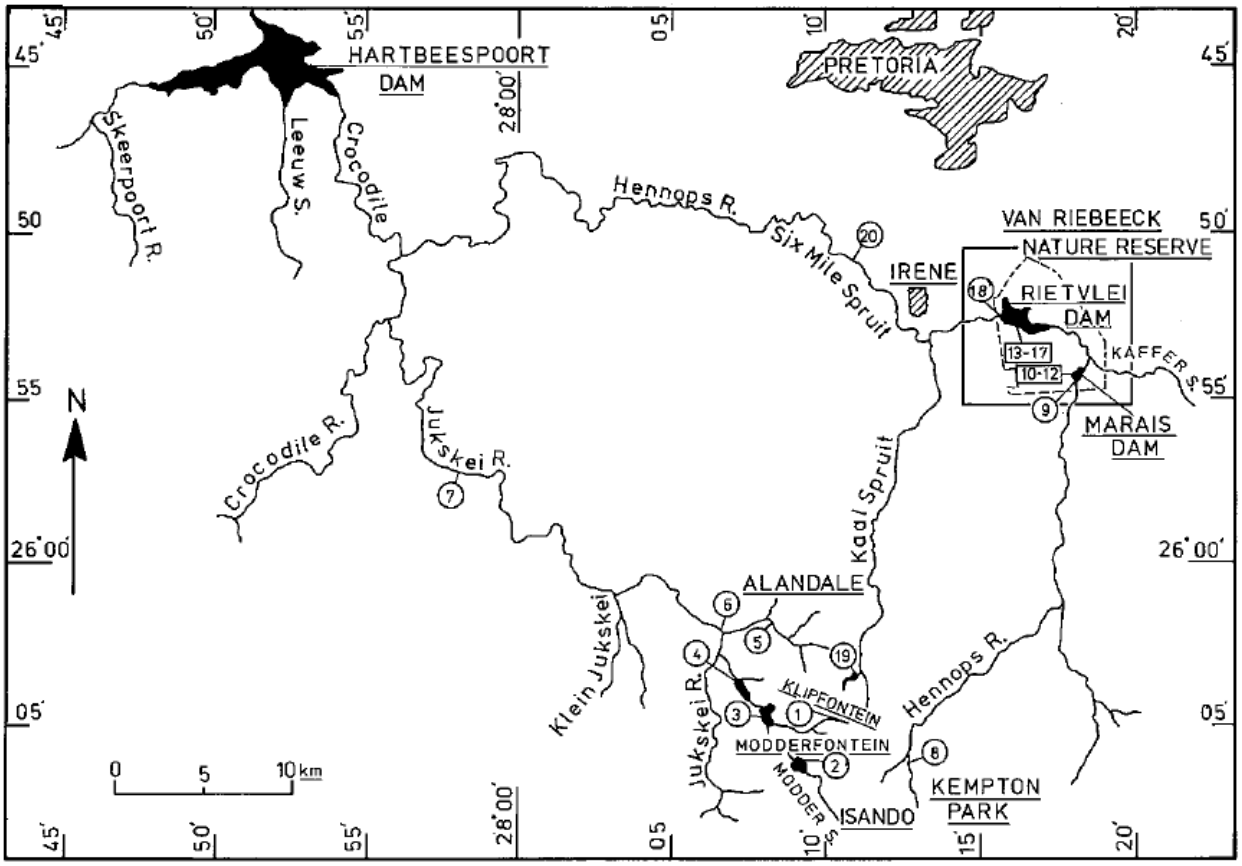

Figure 3.1: Hennops and Jukskei River basins

Hennops is an important natural resource, and known to contribute water needs to the area (Reion4: Integrated Development Plan, 2014). The area is further characterized by ecologically sensitive parts with possible re-development of Centurion lake (Reion4: Integrated Development Plan, 2014). In 1983 Hennops River was described by Sinclair *et.al* (1983) as banked with vegetation. However currently there is less vegetation with the River receiving sewage which causes eutrophication in Wetland of Reitvlei nature reserves (Nyenje *et.al*, 2009). The fact that vegetation which was found in 1983 is no more, is a sign of poor surface water resources management. The River system is further characterized by rapid population growth, with service lacking behind (Reion4: Integrated Development Plan, 2014).

Hennops River is known for being a home of large trees, plants and highly diverse insects and small animals with large ones such as Eland and Kudu which most of them were then threatened by poor water quality from the River (Sinclair *et.al,* 1983; Starting the Hennops

River fountain, 2017). The River used to be a habitat for riparian life and recreation with the surrounding community depending on Municipal tap water for all domestic water needs (Starting the Hennops River fountain, 2017). The research focused at Hennops River, only on parts that passes through Centurion area.

3.4. RESEARCH DESIGN

This section elaborates on what some of the main sources of data was for the study. The study conducted institutional assessment, reviewed existing literature, analysed available raw water quality data, conducted site inspections and interacted with various officials from regulating authorities that assisted in shedding light on the phenomena studied. The main data for the study was analyzed and existing legislative framework too. Data analysis procedure is discussed in detail under point 3.6 of this chapter. Surface water resource management strategies from National government sphere and water quality data were reviewed, compared (within monitored points) and contrasted for contradictions. Members from the surrounding and nearby community also formed part of source of data for the study. Selection procedure that was employed will be discussed under this section.

3.4.1. TARGET POPULATION

Study population is a representation of certain/specific organization or community from whom the information is collected (Ranjit Kumar, 2011). In the case of this study, the population comprised specialists in the field of surface water resources management, the non-governmental organizations, community within the study area and nearby residents (who are not more than 10 km away from the study area. The said specialists included senior and middle management.

The main reason institutional assessment was conducted was to identify potential research participants. Although initially in the research proposal it was anticipated that the core of the study would be institutional assessment, data collected brought about changes. The process therefore served to redirect the data collection processes in terms of potential

research participants. Table below provides quantities of target and sample population of the study.

Target population	**Sample population**
Residents (Along centurion area)	62 interviews given to residents along the Hennops River, Centurion lake and nearby offices, **19 out of 62 returned**
Non-Governmental Organisations	15 interviews given to NGO's involved in Hennops River management (5 for each NGO), **3 out of 15 returned**
Experts in the field of water resources management	3 interviews given to experts, **2 out of 3 returned**
Target population	**Sample population**
Department of Water and Sanitation officials	19 interviews given to DWS officials, **0 out of 19 returned**
COTMM officials	10 interviews given to COTMM officials, **0 out of 10 returned**
Total	**24 interviews**

Table 3.1: Table showing the target and sample population for research area

3.4.2. SAMPLING METHODS

In a research, a researcher wishes to communicate with every individual who may provide all the relevant information pertaining to the research area, but this is nowhere near possible. Therefore, one needs to consider sampling. Sampling method as described by Ranjit Kumar (2011) is a process by which a researcher selects a few individuals, which will serve as a representation of a certain population to give information required. There are various sampling methods and this includes random/probability sampling, Non-probability and mixed sampling. The choice regarding which sampling method to employ during research depends on the type of research, whether the research seeks to gain in-depth knowledge and the population to be sampled. Ranjit Kumar (2011) describes a non-probability sampling method as a method that can be employed when number of elements in a population are

unknown and cannot be individually identified. Non-probability can be used for both qualitative and quantitative (Ranjit Kumar, 2011).

The current study was designed such that it sought to gain in-depth knowledge about the management approaches employed by the regulating authorities in order to comply with the requirements of the South African Water Quality Guidelines for Aquatic Ecosystems (1996). The study furthermore sought to come up with findings, which will be a true reflection of the current management approaches employed. Since the study was both qualitative and quantitative, individuals, which could have had relevant in-depth knowledge, were identified and researcher then made contact with them for further referrals (first research participant approached was former work supervisor). This was done using snowball method and to avoid biasness, initially the study aimed to sample people who are doing the ground work and community members, however only few community members showed interest and willingness to participate in the research.

The researchers approached her former work supervisor, as a specialist, regarding other specialists in the water resources management field and several potential research participants were then identified. One of the government officials, who holds a managerial position then requested a research presentation to the Hennops River catchment management forum meeting. NGO's involved in the Hennops River management were identified during research proposal presentation at the forum meeting and were then approached for interview.

Government departments that play crucial role in water resources management field were identified through institutional assessment as indicated above. The Heads of each department were approached on a face-to-face meeting, with details of research and seek to be allocated officials to interview.

As already mentioned under population, members of the community which were within Centurion area and 10 km radius of Hennops River were identified and random samples were therefore taken for interview and questionnaire purpose. In terms of community members, the ward councilor was approached to discuss the intention prior to communicating with the community members.

Again, for the purpose of gathering in-depth knowledge and making solid recommendations, expert sampling was employed to identify experts in the water resources management field in particular, which were not involved in management of Hennops River but may provide crucial information. This included experts across other Municipalities.

3.5. DATA COLLECTION METHODS

This section discusses the data collection tools that were utilized during the study. The study intended to gather in-depth knowledge first by conducting literature review, which is Chapter two of this research report. Other tools which were deemed crucial in order to achieve the set objectives were interviews, questionnaires, site inspections (Observations) and water quality data analysis.

3.5.1. INTERVIEW

An "interview is a conversation, whereby the purpose is to gather descriptions of the interviewee with respect to the interpretation of the meaning of described phenomena" (Kvale, 1996: quoted by Alshengeeti,2014: Pg 40). Interviews does not only build holistic view points, analyze words, report the views of research participants in detail, it however allows and provides time for interviewees to express their knowledge, feeling and thoughts thoroughly so (Alshenqeeti, 2014).

Interview comprise of three types VIZ Structured, semi-structured and unstructured (Batmanabane and Kfouri, 2017). The structured interview takes place in the form of structured questions, unstructured interview is basically guided by conversation with no specific predetermined questions while semi-structured structured takes form of predetermined open-ended questions. When we look into the semi-structured interview, this types of interviews allows for other questions which may emerge from dialogue between interviewer and interviewee for the study. The semi-structured one allows for information that can be gathered using either structured or unstructured form of interview to be made available. Therefore, during the course of the study, semi-structured interviews were conducted to participants who agreed to participate in the study, due to reasons stated above and the fact that it is a flexible form and will thus allow participants freedom to express their

views. None of these interviews were recorded, they were only written in the interview guide.

3.5.2. OBSERVATION

Since the study was interested in both the actual situation at the study area and perception of individuals and officials of the government, in which case perception part was covered during the interview and questionnaires, observations were conducted in an effort to capture the current situation at the study area. Observation is described by Ranjit Kumar (2011) as another method of collecting primary data which is set for a specific purpose, while ensuring systematic and selective data is collected. Observation took place in the form of site inspection, where pictures were also taken and discussed. Observation can take place in the form of participatory and non-participatory, in which case participatory observation is when a researcher gets to directly partake in activities of the group with the latter entailing that the researcher refrains from partaking in group activities but remain a passive observer (Ranjit Kumar, 2011).

The study conducted non-participant observation due to the fact that there were no pre-known activities taking place at the study area.

3.5.3. WATER QUALITY DATA REQUEST

Water quality data was obtained from DWS Water Monitoring System for the years 2017,2018 and 2019. The available data was not consistent in terms of the constituents monitored and months which were monitored. The period 2017 to 2019 was the most consistent in terms of monitoring data which was available on the WMS website. Therefore, for the missing data, and for months which were not monitored, the results were recorded as 0 mg/l for the purposed of graph plotting. A high level of inconsistency was noted in terms of data for the monitored constitutent and therefore only Nutrients were then selected for analysis.

3.6. DATA ANALYSIS PROCEDURE

Data analysis is a process by which explanation, understanding and interpretation is made from raw data (Sunday, 2016). Within the process of data analysis, there are methods which varies. Therefore, the method employed for data analysis is very crucial since it will ensure that the aim and objectives of the research are realized.

Raw data collected was initially subjected to editing which ensured elimination of inconsistencies and incompleteness. Main themes were identified through analyzing the content of information gathered from interviews and observations. There are two commonly used approach for data analysis and these are deductive and Inductive approach, where deductive approach entail looking into similarities and difference in research questions (Sunday, 2016). The study used deductive approach to analyze questionnaires. Results were then reported in form of graphs and this graph were accompanied by description.

Water quality data was obtained from DWS Water Monitoring System for the years 2017,2018 and 2019. The available data was not consistent in terms of the constituents monitored and months which were monitored. Therefore, for the missing data, and for months which were not monitored, the results were recorded as 0 mg/l for the purposed of graph plotting. A high level of inconsistency was noted in terms of data for the monitored constituent and therefore only Nutrients were then selected for analysis and interpretation.

In terms of measuring the effectiveness of current institutional framework [research objective (i)] , this was done in terms of verification against the set legislative requirements as presented under section 2.4 of chapter two(NWA), which was then followed by verification of intergovernmental cooperation. Verification of each departmental legal mandate implementation as per NWA. Effectiveness of compliance enforcement was measured by site inspectionwhere photographs were taken and corroborated with interviews finding for certain specific interviews and questionnaire questions.

3.7. LIMITATION OF THE STUDY

The research was limited only to the study area which is Hennops River and the immediate surrounding area being Centurion. Since the study area falls under the jurisdiction of COTMM, the study was only focused on the Region with which the study area falls under, being Region 5. Limiting the study area to Region 5 of COTMM made it difficult to identify upstream and downstream pollutants, however, in an effort to remedy this limitation, water quality data for upstream and downstream was analysed and interpreted.

The study used institutional assessment data dating back from the time when the first National Water Act was enacted (1998) till now. The Water Service Act no 108 of 1997 which prescribes the duties of Municipality was not looked into since it came into effect prior to promulgation of the National Water Act, 1998.

In terms of interviews and questionnaires, the two processes were only conducted strictly to community members within Centurion area, NGO's involved in Hennops River management and specialist within water resources management sector. With regard to government officials from all spheres of government (National, Provincial and local) who are involved in surface water resources management, request to conduct interviews was made to the officials who, most of them, did not respond to the request and others requested a formal research presentation to be conducted. The researcher was then invited to the Hennops River forum where at the end of the forum the researcher presented the intentions of the current research study and then handed over the research questionnaires. None of the government officials from Hennops River forum responded back with a filled in questionnaire.

Site inspections conducted was only limited to the study area and by so doing the researchers intention was to draw up observations made from site inspections.

There were some gaps experienced during data collection, specifically interviews and obtaining questionnaires from officials and members who indicated unavailability for interviews. Officials from DWS were all not available for interviews and when questionnaire was submitted to them, none of the participants filled out the questionnaire and forwarded

back to the researcher. With regard to COTMM, the Head of Department only allocated specific number of officials to participate in the study to which none all of them where available to participate in either interview or questionnaire. Centurion hotel, where Centurion Lake passes, the stuff members was unable to freely participate in the study and when the General Manager was approached for authorization, he also indicated lack of comfortability in having his members participate in the research however the manager himself was able to forward back a filled in questionnaire. Another inevitable limitation that the study experienced was government officials from all spheres of government not participating in the research study and failure to issue out water quality data and the register of both authorized and unauthorised water users. This therefor affected the study, where research objective (i) was not achieved. Furthermore, research questions (i) and (i) under chapter one was also not answered. Noticing that the research participants (government official) were not responding to the request of interview and questionnaire, the researcher then approached Assistant Director of DWS regarding the intention to have interview with herself and some of officials under her directorate. A request was made for a formal presentation of the research so as to gather in-depth and clarity regarding the intention and extent of the study. To which the researcher complied with the request and conducted presentation during the Hennops River forum, so as to remedy the foreseeable research limitation. In terms of water quality date, the researcher resorted to use of raw water quality data which has been published on Water Monitoring System (WMS), even though the data was not consistent throughout the monitoring periods but it assisted in remedying the lack of provision of data from DWS and COTMM.

CHAPTER FOUR

EMPIRICAL EVIDENCE

4.1. INTRODUCTION

This chapter is dedicated to presenting results of data collected during the research study in an effort to provide answers to the the research questions presented in chapter one. To ascertain the current water quality status of the Hennops River system, water quality data analysis was carried out for the available water quality data. Interviews were also conducted and to corroborate results of interviews, site observations were conducted. The study was unable to answer whether the authorized water users comply with the requirements stipulated on the water use licence. An assessment of threats was also carried out to verify if compliance enforcement exists or not and whether it is effective in protecting of Hennops River system by the regulating authority. To substantiate the effectiveness and/or lack thereof of the current institutional framework in management of surface water resources, institutional assessment was conducted and the theoretical background of the assessment is under chapter two. The legislative development was at the Centre of the said process in order to elaborate more on the current institutional development. Gaps in implementation of the legal requirements and associated institutional requirements are highlighted under this chapter.

4.2. ASSESSMENT OF THE WATER QUALITY STATUS OF HENNOPS RIVER

Under this section, the study sought to establish the current water quality status in terms of the SAWQG:AE. Firstly, summary of the requirement of the SAWQG:AE will be presented then followed by the current water quality status in the form of analysis of raw water quality data and site observation.

4.2.1. SUMMARY OF THE SAWQG: AE

The SAWQG: AE is volume number seven amongst a series of eight water quality guidelines South Africa, 1996). The South African Water Quality Guidelines serves as the primary source of the information in which the requirement for setting the water quality

requirements are to be strictly derived from for all water uses of surface water resources and protection thereof (South Africa, 1996). The South African Water Quality Guidelines provides associated management guidelines, different approaches and evaluation criteria thereof.

4.2.1.1. IMPORTANT CHARACTERISTICS OF AQUATIC ECOSYSTEMS

Differences exist between approaches which water managers are to use for determining the water quality requirements for protecting and maintaining the health of aquatic ecosystems compared to the approaches used to determine the requirement of water uses (South Africa, 1996). Characteristics, which were considered when developing the South African water quality guidelines: Aquatic ecosystems were:

I. Complex systems-In short, numerous species, habitats, process and water users; and

II. Aquatic habitat-Habitat for aquatic organisms (South Africa, 1996).

4.2.1.2. IMPORTANT CHARACTERISTICS OF AQUATIC ECOSYSTEMS

When we look into the guideline, the Targeted Water Quality Range (TWQR) (South Africa, 1996) is used as a management tool that identifies constituent's concentration to be set at ideal concentration range and/or quality requirements for a particular constituent (South Africa, 1996). When the TWQR has been exceeded, the Chronic Effect Value (CEV) is used, which is a tool that is used to evaluate the health and integrity of aquatic ecosystems (South Africa, 1996). When the surface water resources have reached and is exceeding the CEV, then the Acute Effect Value (AEV) should be set. The AEV is a tool that alarms water managers on cases that requires urgent management attention (South Africa, 1996).

The guidelines make provision for urgent management intervention on cases of which the water quality within that particular stream have exceeded the CEV, only where the AEV have been set. Furthermore, the guidelines provide for modification of criteria set out only on terms that modified criteria must afford the same level or more of protection as per the unmodified criteria.

4.2.1.3. WATER QUALITY CONSTITUENTS

The SAWQG: AE, chapter 6 contains information relating to chemical constituents along with the TWQR, CEV and AEV for all constituents deemed relevant for maintaining a healthy River system. Tables below were deduced and will thus be used to guide analysis of raw water quality data; other constituents are attached to Appendix H of this report.

Minimum value		Definition	
7-day mean minimum concentration		Recorded at an hourly basis over a 24 hour cycle for seven day cycle	
1-day minimum concentration		The concentration recorded instantly at a 24 hour period or at sunrise	
TWQR and criteria	concentration	Condition	Application
TWQR	**80%-120% of saturation**	**06h00 sample or lowest instantaneous concentration recorded in a 24-hour period**	"Will protect all life stages of most southern African aquatic biota endemic to, or adapted to, aerobic warm water habitats. Always applicable to aquatic ecosystems of high conservation values" (South Africa, 1996)
	>60% (Sub-lethal)	7-day mean minimum	"The 7-day mean minimum and the 1-

Minimum allowable values	>40% (Lethal)	1-day minimum	day minimum should apply together. Violation of these minimum values is likely to cause acute toxic effects on aquatic biota." (South Africa, 1996)

Table 4.1: Dissolved Oxygen (South Africa, 1996)

Water resource	TWQR
All aquatic ecosystems	• pH values are limited to not being greatly different from the the background pH values of specific water body and at any time of the day, by >0.5 of a pH unit, or by >5%, or whichever estimate is the more conservative.

Table 4.2: pH (Acidity and Alkalinity) (South Africa, 1996)

Water resource	TWQR
All surface waters	• Throughout the year, for specific water body, inorganic phosphorus should not be allowed to change by less than 15% when the water body is unimpeached; • Trophic status decrease I allowable, however it should not increase from the current status; and

	• From a given measured period, the rate of inorganic phosphorus concentration must not be altered

Table 4.3: Phosphorus (Inorganic) (South Africa, 1996)

Water resource	TWQR
All aquatic ecosystems	• Temperature for a specific water body should not change from the normal daily water body temperature for that particular water or by >2^0C, or by > 10%, whichever estimate is the more conservative

Table 4.4: Temperature (South Africa, 1996)

Water resource	TWQR
All inland waters	Throughout the year, when condition are not impacted upon, TDS should not be allowed to decrease to less than 15%

Table 4.5: Total dissolved salts/Solids (South Africa, 1996)

All aquatic ecosystems	TWQR
Background TSS concentration are <100mg/·	For an identified site, the TSS should not be allowed to increase to greater than 10% of the background TSS at a specific time

Table 4.6: Total Suspended Solids (South Africa, 1996)

In terms of the bacteriological constituents, the SAWQG: AE does not cater for these constituents rendering water quality management-institutions, to rely on general and special limit (South Africa, 1999). The general and special authorization provides wastewater limit values applicable to discharge of wastewater into a water course (South Africa, 1999). Below is a table of the said limits:

Substance/parameter	General limit	Special limit
Faecal Coliforms (per 100 ml)	1000	0
Chemical Oxygen Demand (mg/l)	75	30
pH	5.9-9.5	5.5-7.5
Ammonia (ionised and Un-ionised) as Nitrogen (mg/l)	3	2
Nitrate/nitrite as Nitrogen (mg/l)	15	1.5
Chlorine as free chlorine (mg/l)	0.25	0
Suspended solids (mg/l)	25	10
Electrical conductivity (mS/M)	70 mS/m above intake to maximum of 150 mS/m	50 mS/m above background receiving water, to a maximum of 100 mS/m
Ortho-Phosphate as Phosphorus (mg/l)	10	1 (median) and 2.5 (Maximum)
Flouride (mg/l)	1	1
Soap, oil or grease (mg/l)	2.5	0
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
Disspolved Copper(mg/l)	0.01	0.002
Substance/parameter	General limit	Special limit
Dissolved Cyanide(mg/l)	0.02	0.01
Dissolved Iron(mg/l)	0.3	0.3
Dissolved lead(mg/l)	0.01	0.006
Dissolved Manganese(mg/l)	0.1	0.1
Mercury and its compounds(mg/l)	0.005	0.001
Dissolved Selenium(mg/l)	0.02	0.02
Dissolved Zinc(mg/l)	0.1	0.04
Boron(mg/l)	1	0.5

Table 4.7: General and Special Limits (South Africa, 1996)

4.2.2. STATUS OF WATER QUALITY WITHIN HENNOPS RIVER SYSTEM

4.2.2.1. WATER QUALITY MONITORING PROGRAMS GUIDELINE

In respect to the South African water resources management sector, the WQM programme guideline document for surface water resources does not exist, however for certain industries such as mining, the DWS has adopted the Best Practice guidelines to assist in enhancing water resources protection in the South African Mining industry. Monitoring programs are therefore informed largely by the South African Water Quality Guidelines. These guidelines consist of a series of 8, the one most applicable is dependent on the intended type of use of a particular water resource.

4.2.2.2. WATER MONITORING SYSTEM

The DWS established WMS, which is a browser tool that provides access to the DWS water monitoring points and associated raw water quality data (Department of Water and Sanitation, 2016). The implementation of the website allows interested and affected parties, NGO's and any other concerned member of the community to access raw water quality data on this website and be informed of the status of water quality within the water resources of their interest. On the WMS website, water quality data for the study area is packaged under Crocodile West and Marico WMA since they are still grouped as the old 19 WMA. The website consists of raw water quality data for the study area up to the year 2018. Some of monitoring points does not have the complete data set.

4.2.2.3. WATER QUALITY RESULTS AND ANALYSIS

Five monitoring points were identified from the WMS website. From the five monitoring points, four had raw water quality data, which was within the duration that the study intended to look into and analyze. The reason for the period chosen for analysis is stated under section 3.5.3 in chapter three. Therefore, the study obtained data for the four monitored points. Figure below shows example of water monitoring points as obtained from google earth map, the remaining points are attached to Appendix I:

Figure 4.1: Water monitoring point-195445: Centurion at Centurion Lake
(Google earth, 2019)

As indicated under chapter three, of the constituents monitored by DWS, the Nutrients (Nitrate/Nitrite and Phosphates) were abstracted for analysis. The following graphs presents results of nutrients analysis for the four monitored points, with each monitoring point plotted against the general limit (GL) and special limit (SL) requirements:

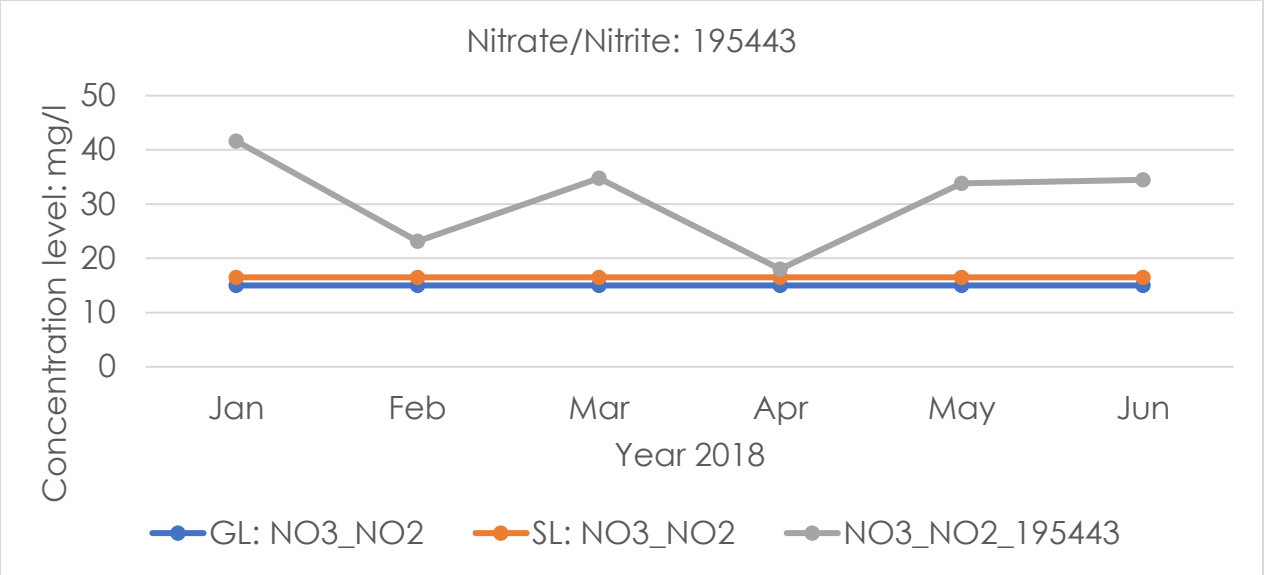

Figure 4.2: Graphical plots of NO_3_NO_2 for monitoring point 195443

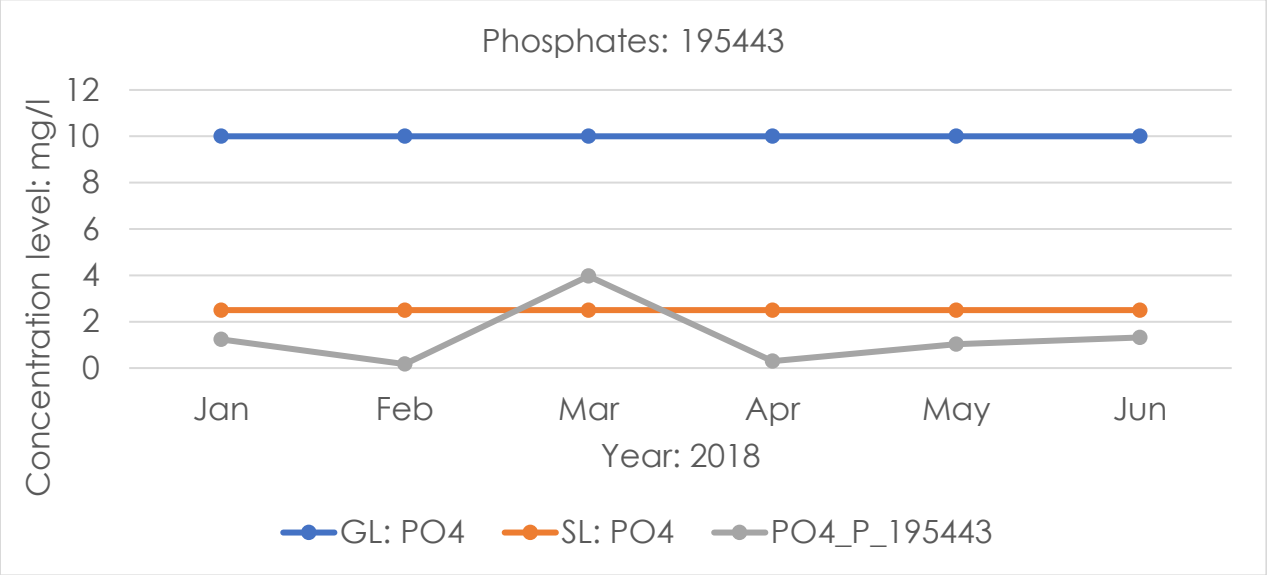

Figure 4.3: Graphical plots of PO_4 for monitoring point 195443

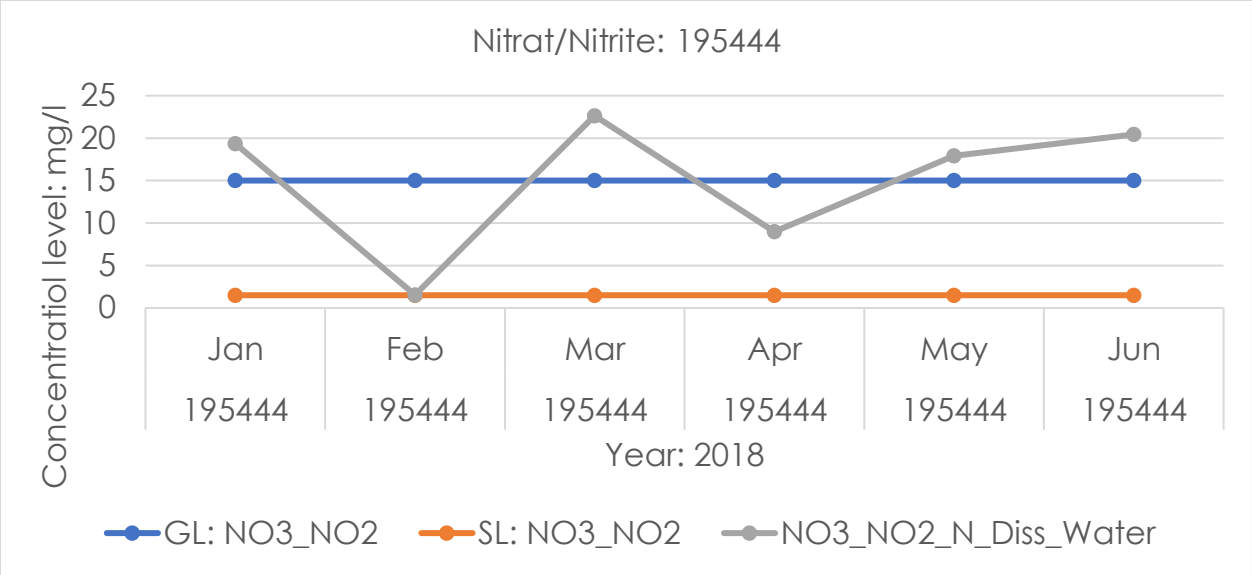

Figure 4.4: Graphical plots of NO_3_NO_2 for monitoring point 195444

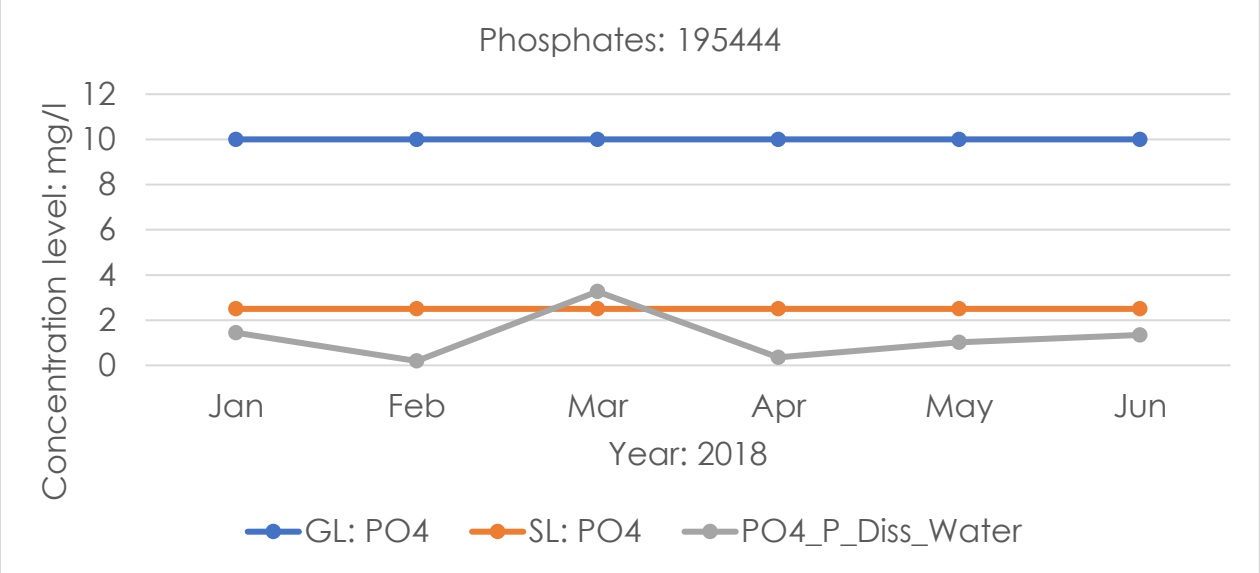

Figure 4.5: Graphical plots of PO_4 for monitoring point 195444

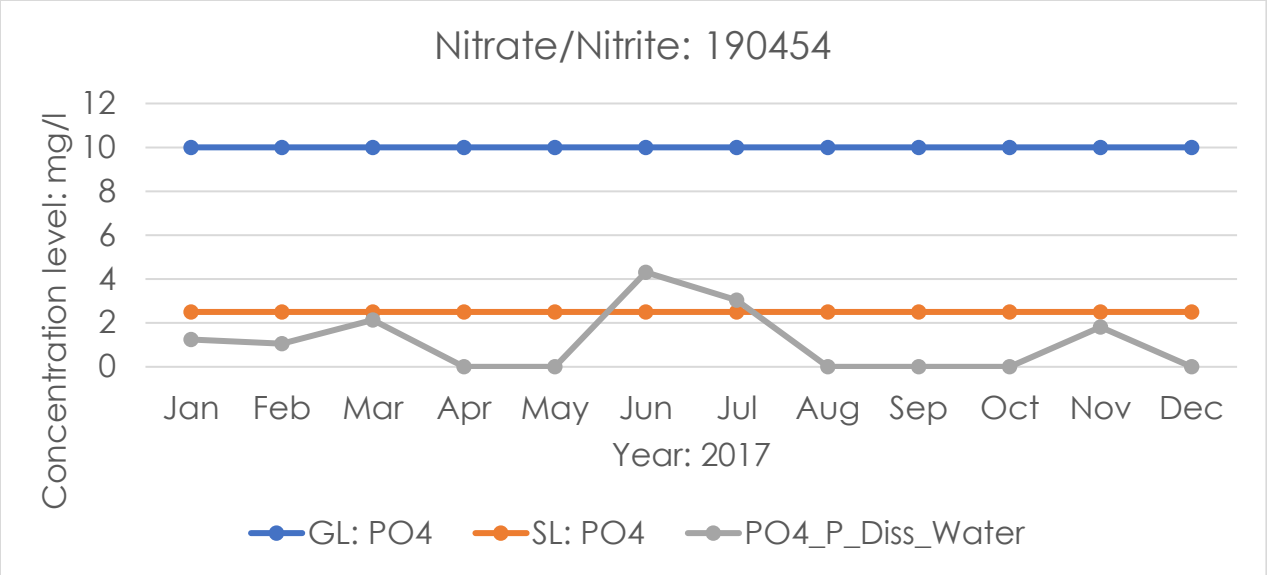

Figure 4.6: Graphical plots of NO_3_NO_2 for monitoring point 190454

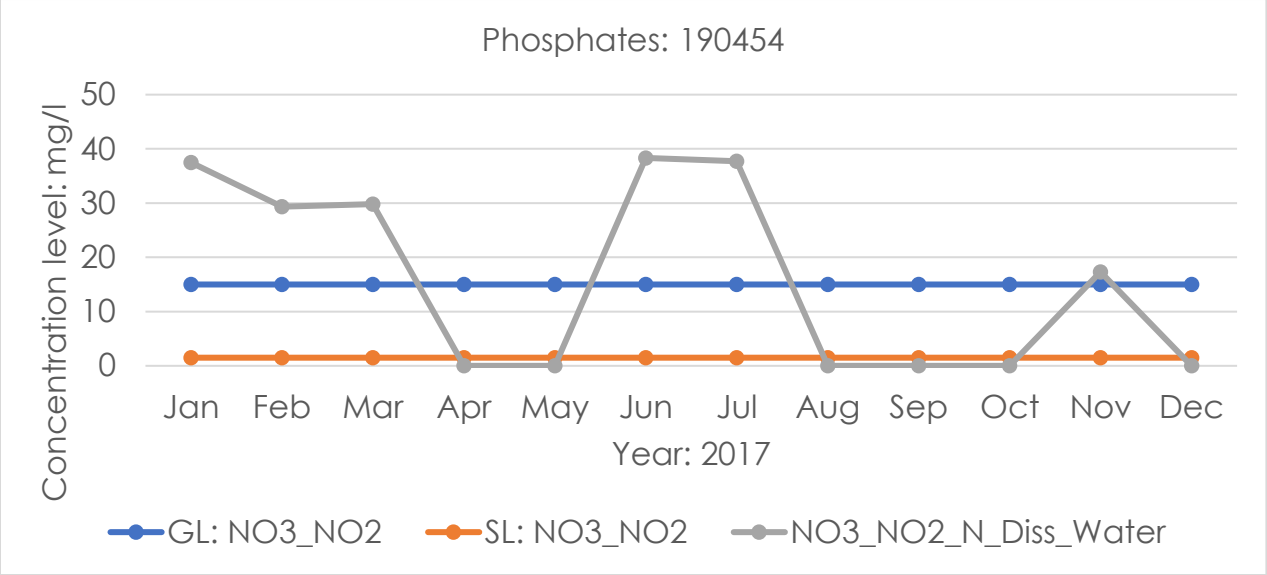

Figure 4.7: Graphical plots of $PO_4$for monitoring point 190454

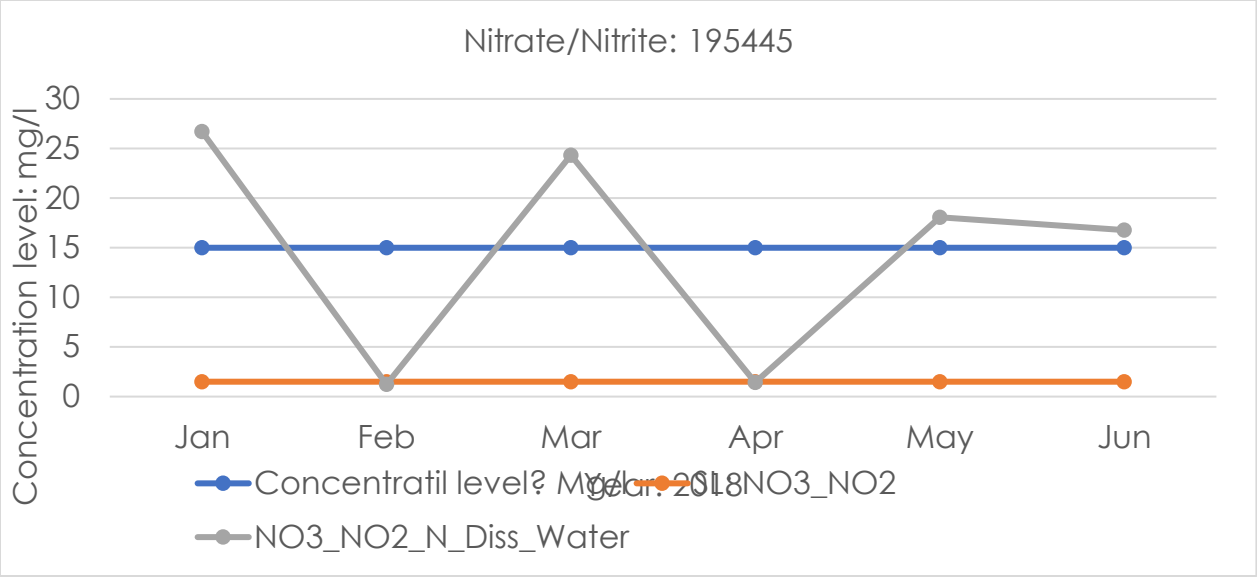

Figure 4.8: Graphical plots of NO_3_NO_2 for monitoring point 195445

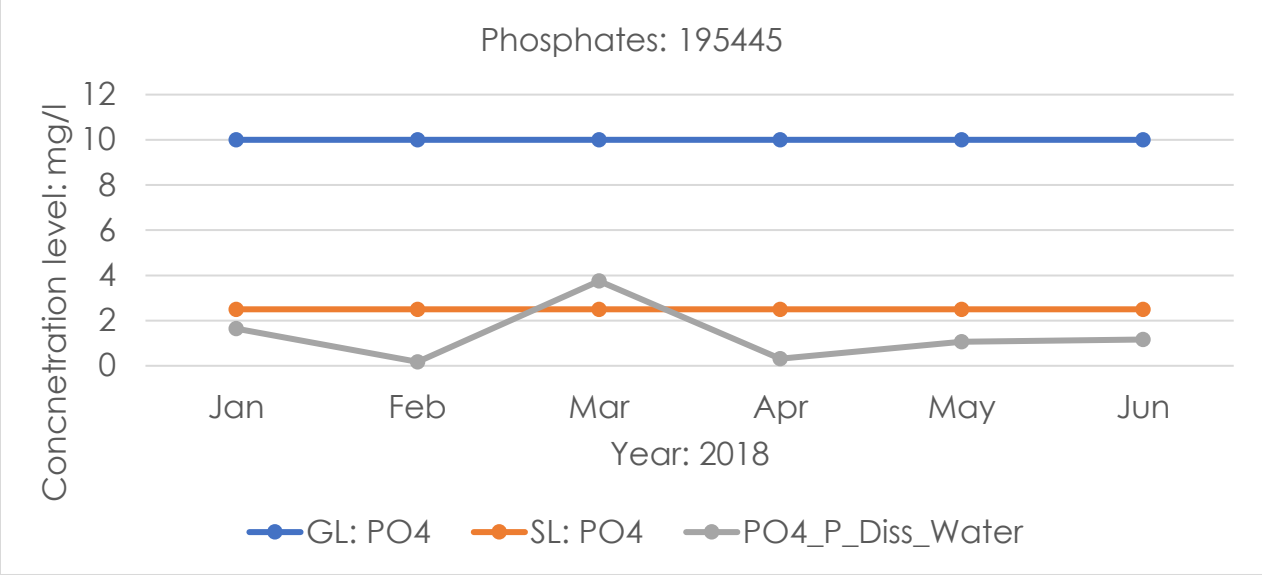

Figure 4.9: Graphical plots of $PO_4$for monitoring point 195445

The Nitrate/Nitrite graphs shows an increasing trend, which are higher than the GL and SL. Where there is a sudden decrease resulting in graphs dropping to 0 mg/l this is when there were no samples taken for analysis. Monitoring point 190454 has only seen non-compliance during months June and July. Figure 4.10 monitoring point 190454 shows excess of

Phosphates in the stream from discharge point by the Sunderland Ridge WWTP while other monitoring points remains slightly non-compliant to the GL and SL.

4.2.2.4. OBSERVATIONS

In a survey conducted along Hennops River in Centurion, it was established that all concerns and challenges raised by residents along the Hennops River range from presence of raw sewer, miscellaneous solid waste thrown into the River and not being removed timeously, to water within the River not being visually appealing were true. When respondents were asked the question: *"In terms of visual appeal, how is the River when you access it?"*. 38% stated "*Dirty"*, with two respondents stating the following:

"Very dirty, nothing can survive in that River".

"It is always dirty, I have never seen any changes.

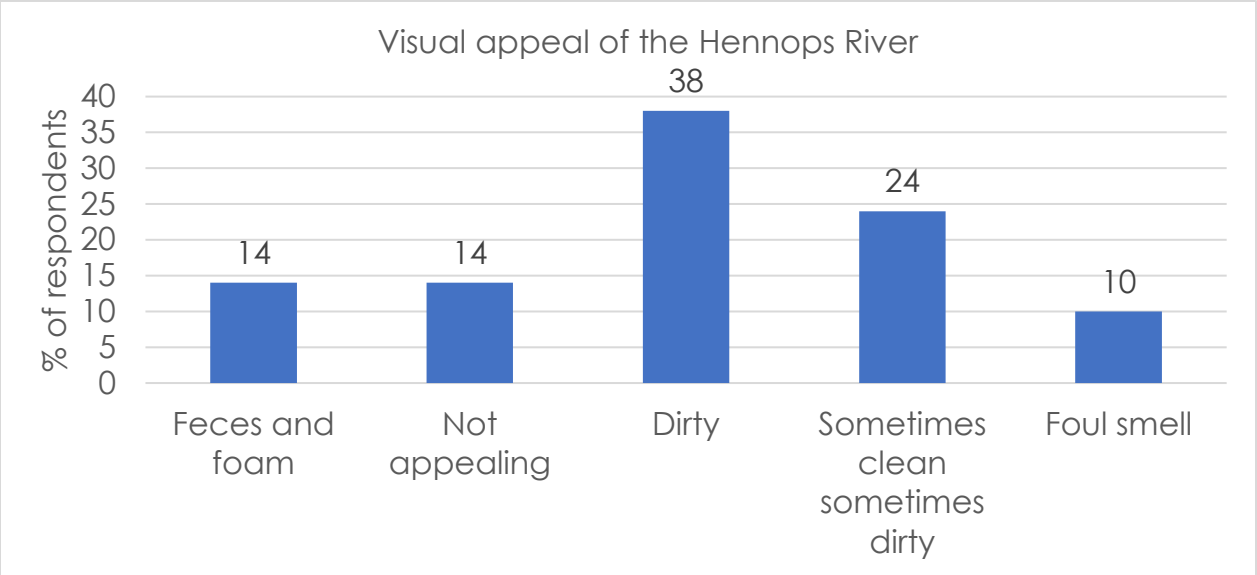

Figure 4.10: Graphs showing percentage respondents to activities taking place within Hennops River and visual appeal Hennops River (see appendix F).

Five broad themes emerged from analysis of questionnaires for the question that required list of activities taking place at the Hennops River. These themes were "Rituals, Nothing, Fishing, Baptism and Washing". As presented on figure 4.11, Rituals is the most highest

followed by "Nothing". Dirtiness in the River is articulated to these activities. It was further noted that most of the respondents who responded by saying "nothing' were the ones where the stream was either passing along their premises or were in very close proximity with the stream. It could be that these participants were actually hiding something, which the study was unable to identify.

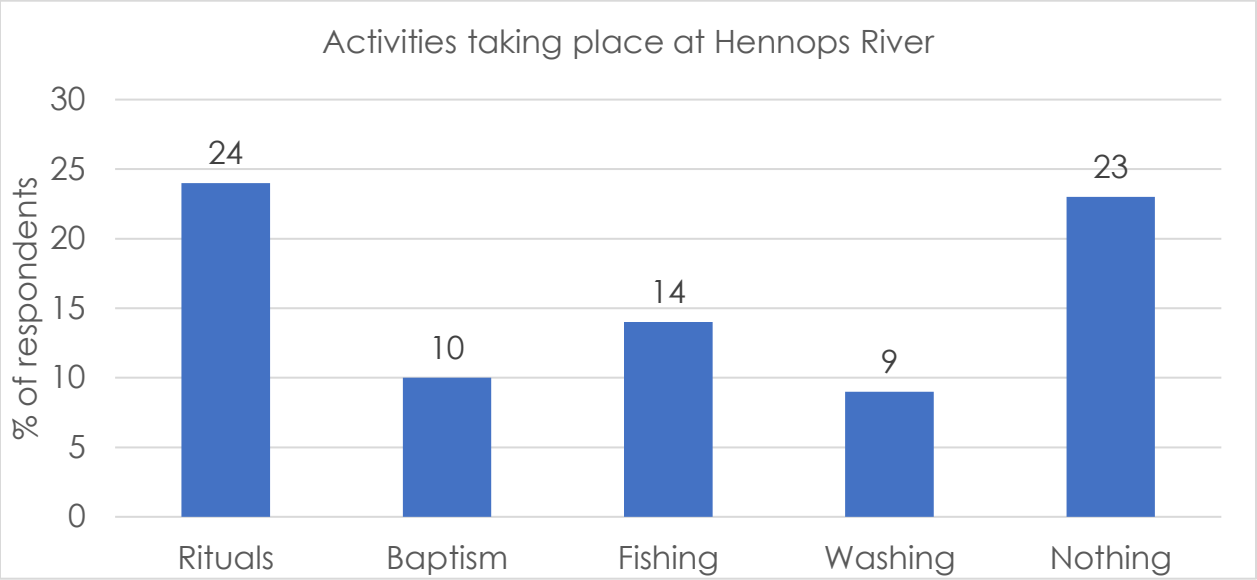

Figure 4.11: Graph showing respondents answers to list of activities taking place at the Hennops River. Graph based on filed data (See appendix F)

Another section of the questionnaire required the respondents to provide information pertaining to pollution incidents (Figures 4.3 and 4.4). 65% of the respondents indicated that pollution incidents occur daily along with 60% respond saying "never' to the question: "*How long does it take for pollution incidents to be attended to*?".

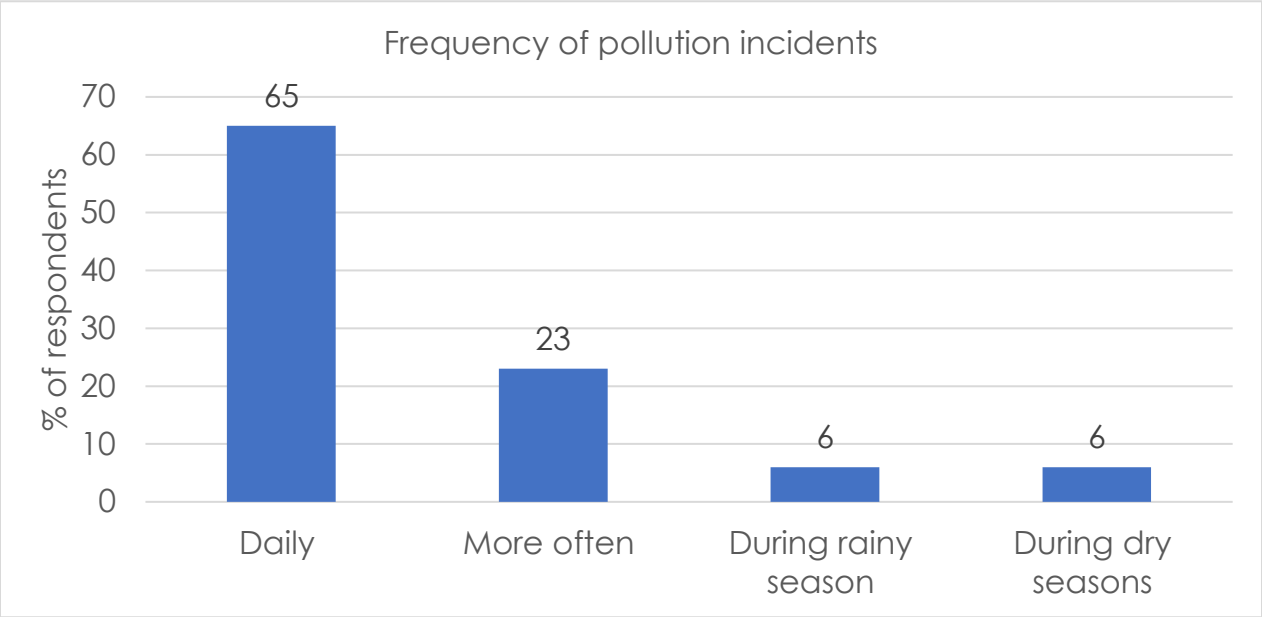

Figure 4.12: Graph showing respondents answers to frequency of pollution incidents. Graph based on filed data (See appendix F)

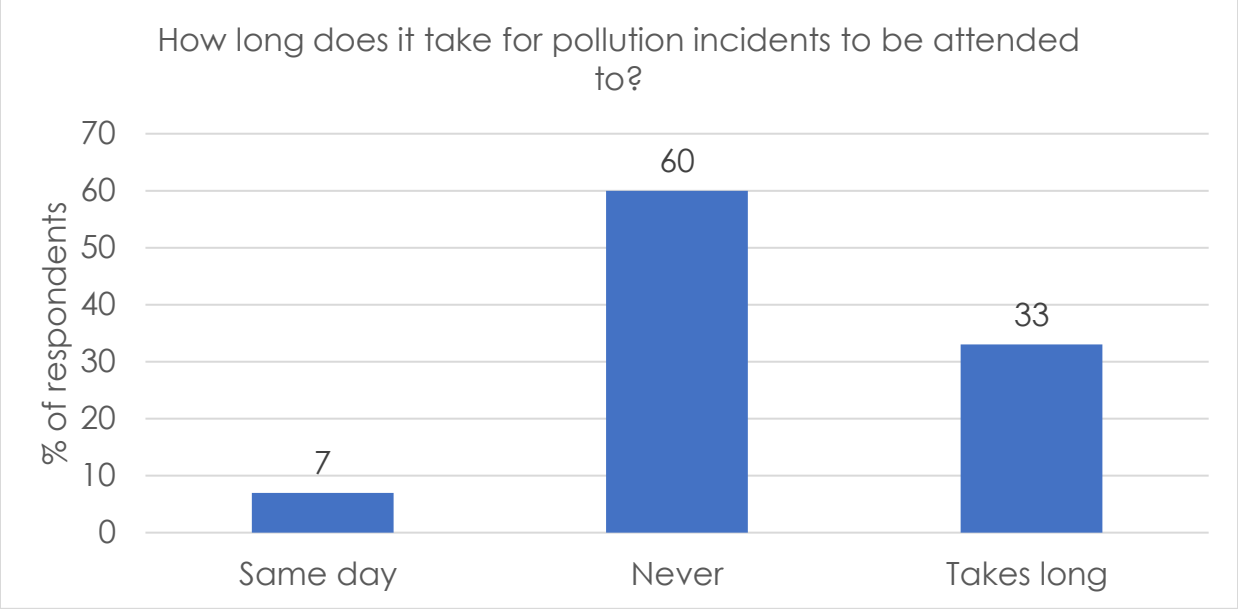

Figure 4.13: Graph showing respondents answers to "How long does it for pollution incidents to be attended to?". Graph based on filed data (See appendix F)

The information from questionnaires is also supported by the visual observation made during the study period. Figures 4.5 to 4.11 corroborate these issues.

Figure 4.14: Evidence of raw sewer in Centurion Lake

(Photo taken in August 2019)

Figure 4.15: Algal growth in the Hennops River

(Photo taken in August 2019)

Figure 4.16: Evidence of trees residuals in Hennops River

(Photo taken in June 2019)

Figure 4.17: Shows another evidence of trees residues not removed from Hennops River

(Photo taken in August 2019)

Figure 4.18: Pilled up solid waste along Centurion Lake

(Photo taken in June 2019)

Figure 4.19: Evidence of solid waste removal along Centurion Lake

(Photo taken in August 2019)

Figure 4.20: Shows foam in the Hennops River
(Figure taken in August 2019)

However, residents downstream of the Hennops River did highlight during interviews that water within the stream is sometimes clean as on figure 4.10. The residents articulated this to rainfall since this is apparent only during rainy seasons. One participant commented that:

> *"Sometimes clean, sometimes dirty. When it is raining it gets clean and during dry seasons it is extremely dirty"*

4.3. ASSESSMENT OF THREATS TO THE HENNOPS RIVER SYSTEM

Surface water resources protection can be done from an individual perspective, organization (e.g. NGO) and governmental level. Either way, there are still threats that will require collective commitment. This section discusses all the threats, specific to the Hennops River System.

4.3.1. WATER USERS

The aim of this section was to identify all water users of the Hennops River through assistance of the regulating authorities being Department of Water and Sanitation and COTMM. This is because water user's impacts direct on the quality of water within the water resource. Both departments refused to communicate and provide information pertaining to the water users and this then rendered the study unable to realize its initial intention. Despite the refusal to provide such information, during interviews some residents were able to provide information pertaining to water users.

4.3.1.1. AUTHORIZED WATER USERS

Within the study area, Sunderland Ridge WWTP is the authorized water user that discharges into the Hennops River. It is important now to indicate that the DWS policy has mandated all the water users to ensure that they treat their effluent before the water is returned to the natural watercourses in order to obtain maximum utilization of scarce water resources (South Africa, 1996). Suspicion exist around noncompliance of the Sunderland Ridge WWTP that it is not compliant to their water use licence. As stated by one participant from local authority that some WWTP are not compliant to their water use licence when asked "in your opinion, what do you think is the contributing factors to the current status of surface water resources?":

> *"Wastewater treatment plants not meeting capacity. Only one WWTP that meets the requirements, resulting in others discharging pollutants to the stream. Infrastructure does not support the growing demand".*

When probed furthermore in an effort to get exact names of the WWTP that are not meeting capacity, the participant refused to express his opinion.

DWS WQM programme for Hennops River has been stopped with the last sampling done in the year 2018, however COT has an active monitoring programme. Taken together with figure 4.7, it can be concluded that Sunderland Ridge remains a threat to the Hennops River systems Health.

On the questionnaires, the respondents were asked to indicate if they have noticed any activities taking place in the stream, which they suspect to be a legislated activity, which had to be authorized prior to taking place. Fifty three percent of those who responded to the question indicated that there were none which they know of. Other research participants responded "Nothing" to the question that requested types of activities which they have witnessed taking place in the Hennops River. These research participants are the ones where the stream either passes directly within their premises or are staying in the close proximity of the River bank. A possible explanation for this response by the research participants night be that the research respondents are actually the ones who are directly polluting the River hence they were unable to provide precise answers.

4.3.1.2. UNAUTHORISED WATER USERS

During interviews with residents, some residents indicated that the community members mostly use the River for rituals. Officials which were present at the Hennops Catchment Forum meeting indicated that they are aware of the unauthorized water user, however they are not comfortable providing such information. Other community members indicated that they were using the stream for fishing up until the year 2002 when they suddenly notice a great decline in number of fish available in the stream. During inspection along the River, there were no unauthorized activities, which were witnessed by the researcher, however the foam on figure 4.20 is an indication of impacts of some sort of unauthorized activities taking place upstream of Hennops River.

4.3.2. COMPLIANCE MONITORING AND ENFORCEMENT

During interview survey, questions, which were asked, did not entail elaboration pertaining to the smell along the River. Of the sampled population, a larger part raised challenges regarding foul smell from the River. The residents indicated that the smell is more concentrated as you approached the River. One participant along Centurion Lake indicated that:

"Smelly water from the Lake that affected business negatively. Sewer, various objects like old car tyre's, clothing, plastics, tins, branches of trees, shoes, foam and any other rubbish you can think of".

It has been reported that DWS has issued out instruction to COTMM to review water use authorization so as to strengthen compliance and ensure that water quality is improved (Pressreader, 2018).

4.3.3. LACK OF COMMUNITY AWARENESS

When residents who are supposed to be taking care and benefiting from the resource directly pollute a water resource, one can conclude that there is lack of awareness amongst community members. The graph blow depicts results of questionnaire, corroborates this conclusive statement with majority of participants (60%) indicating "No" to the question:

"*Has there been any community awareness conducted by government officials in terms of taking care of the River*":

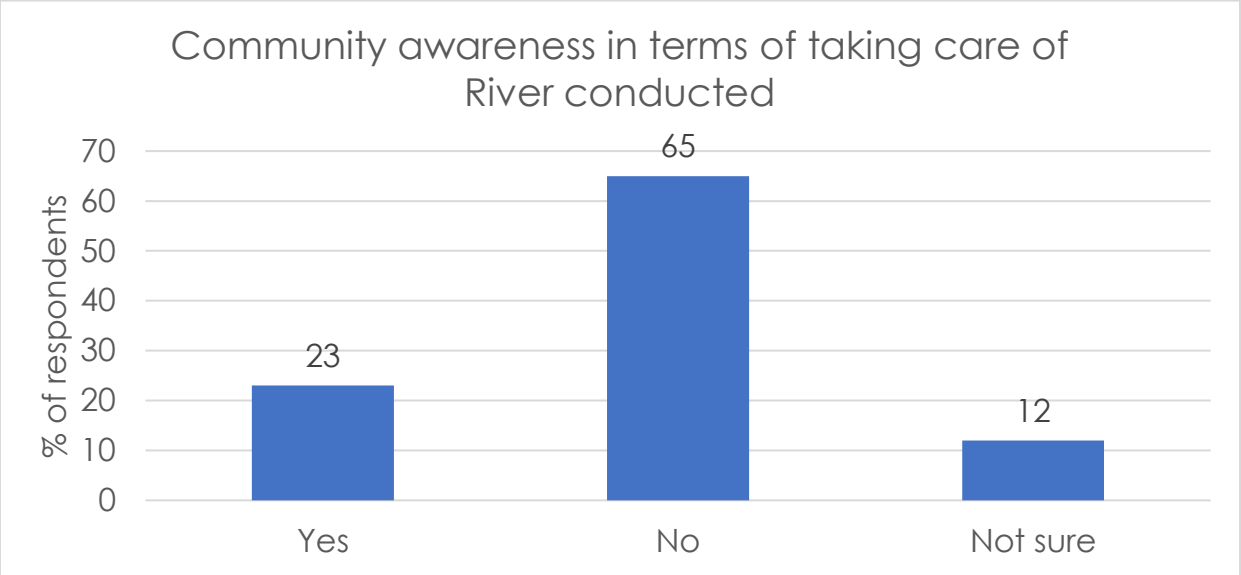

Figure 4.21: Graph showing respondents answers to whether or not has community awareness been conducted. Graph based on filed data (See appendix F)

When the sampled population where asked if the local authorities are doing a great job in terms of taking care of the River, 82% of participants who responded to the question indicated insufficient. Results are presented on graph below.

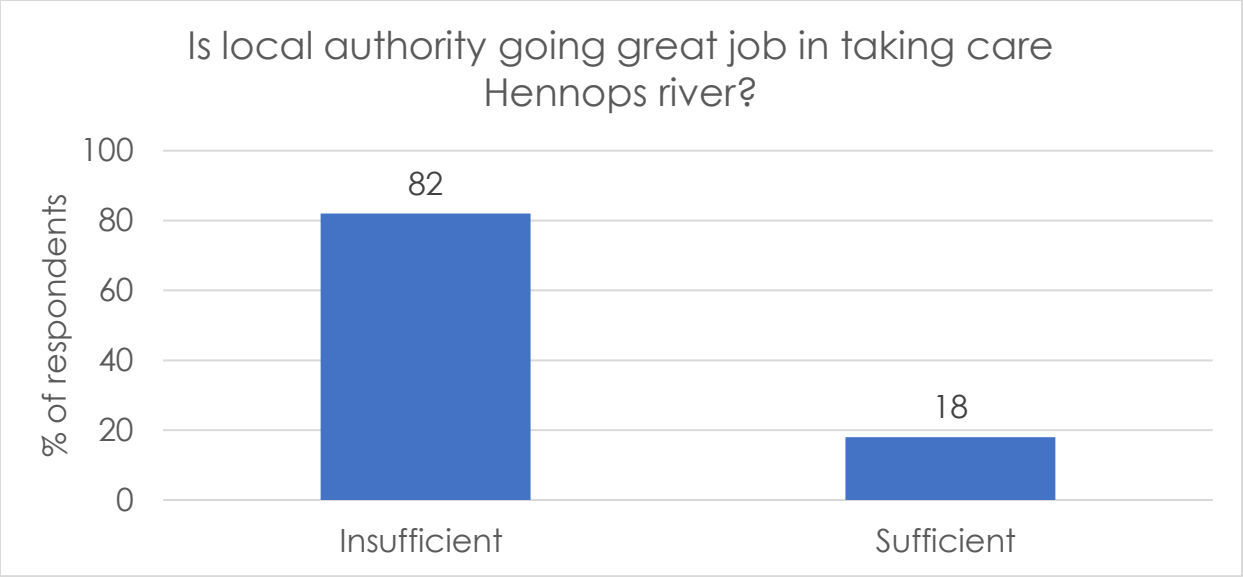

Figure 4.22: Graph showing respondents answers to whether or not local authority is doing great job in taking care of the Hennops River. Graph based on filed data (See appendix F)

4.4. ASSESSMENT OF INSTITUTIONAL FRAMEWORK FOR MANAGEMENT OF WATER RESOURCES

Larger part of the institutional framework has been discussed under section 2.4 and 2.5 of chapter two. Only summary of the assessment findings and the implications are contained in this section.

The study acknowledged change in name of DWS to Department of Water, Sanitation and Settlement. This change came into effect and public announcement following approval of the research proposal and therefore data was collected during the time when the Department was still named Department of Water and Sanitation. For this reason, throughout the study the research has recognized the Department with its former name. Furthermore, in view of the fact that water data for the Limpopo WMA is still packaged under the old WMA being the Crocodile West and Marico, therefor data in this research is presented from the old stand being the Crocodile West and Marico WMA.

Based on the current documents available for public on the DWS website, various white papers were published dating as far back as far as 1994. The first white paper to be published was the one on water supply and sanitation. Another three more white papers namely the National Sanitation Policy, the national Water Policy and lastly on the basic household sanitation during the years 1996, 1997 and 2001 respectively. Literature regarding legislative developments dating back from the time of promulgation of the NWA, focusing specifically on the ones which are important for compliance with the aforesaid guidelines is contained under chapter two, literature review. All other sections of the Act, which are not applicable to Hennops River, such as Chapter 10: International Water Management, Chapter 11: Government waterworks (South Africa, 1996) etc., were not considered due to the fact that the study is not looking into the entire catchment but a River that forms part of a catchment.

The NWA requires that the NWRS be revised every 5 years; however, this aspect is still lagging behind since the time of the first NWRS. Currently all duties of CMA for Crocodile River are currently vested in the Minister of DWS. The study was unable to get hold of information relating to whether the Minister is receiving funding which should been allocated to the CMA, which will ensure full execution of the responsibilities of the CMA. An expert interview with DWS official confirmed that proposed Limpopo North Catchment Management Agency is still awaiting approval by the Minister of DWS. Therefore, there is no Catchment Management Strategy in place for the Crocodile River, which is articulated to no active CMA as indicated under section 2.6.1.2 of chapter two.

In respect to the study area, and despite the fact that the CMA is not yet active, the Hennops River catchment management forum meeting for the Hennops River are actively taking place. This forms part of the establishment and implementation of consultative forums. The representation during these meetings consists of officials from:

- National Government sphere -Department of Water and Sanitation;
- Provincial Government Sphere -City of Tshwane and Ekurhuleni; Metropolitan Municipalities;
- Ward councilor;

- Residents
- NGO's - Hennops Blue Horizons and Bluswirl; and
- I&AP - ERWAT and Extingtion Rebalion water consultants

Issues, which are discussed during the Hennops River forum meetings includes but not, limited to:

- Water quality issues;
- Water quality data from local sphere of government;
- Infrastructure pollution incident; and
- Proposed development project

4.5. SUMMARY

The requirements of the SAWQG: AE for constituent to be monitored to maintain a healthy aquatic ecosystem are lacking. Firstly, the requirements of bacteriological constituents are not included in the guidelines. Secondly, the guidelines are not a progressive document, it has not been reviewed since its first implementation which is the year 1996. SAWQG:AE as a main and foundation source of information in determining the water quality requirements should be in a position to offer supreme water resources protection than its counterparts (e.g. the General Limits and Special Limits) values applicable to discharge waste water into a water course.

Water quality within the Hennops River is such that it cannot provide a healthy habitat for aquatic ecosystems. Fishes are no more and water quality results analysis is outside range of the general and special limit. In terms of compliance enforcement, it was found that there is a need for regulating authorities to strengthen compliance enforcement measures. From the available water quality monitoring results, no constituents could be measured against those contained in the SAWG: AE.

CHAPTER FIVE

ANALYSIS AND DISCUSSION

5.1. INTRODUCTION

This chapter presents analysis of results presented in chapter four. Furthermore, this chapter seeks to fulfil the objectives of the study as outlined in chapter one. Firstly, the implication and effectiveness of the institutional framework along with the institutional legal mandate will be analyzed and discussed as per chapter four. Secondly, the implication of compliance management of both authorized and unauthorized water users will be discussed and lastly the aspects of effective surface water resources management will be discussed.

5.2. IMPLICATION AND EFFECTIVENESS OF THE CURRENT INSTITUTIONAL FRAMEWORK

Above, section 2.4 to 2.5 under chapter two were dedicated to legal framework and institutional assessment. Both legal framework and institutional assessment were discussed under contextualization of literature for the South African context. The first research objective was to identify all institutions and their legal mandate involved in surface water resources management. Therefore, the said two sections addressed the first research objective. This section will now discuss the implication of the current institutional framework and legal mandate. In doing this the second research objective will be achieved.

Within the research area, DWS is the custodian of water resources with CTMM as the local sphere of government. There is no provincial sphere mandated for surface water resources, therefore duties of the provincial sphere have been vested to the DWS. When duties of another department are vested into another department, which also has its own mandate to fulfil, certain duties of that department may not be fulfilled entirely. This is evident globally with specific reference here made to the Guzelyurt area situated within the Cyprus Region where Arslan and Akun (2018) came up with various findings. The researchers found that the responsibility of surface water resources management, water quality monitoring to be specific, had been delegated to a single government department (Arslan and Akun, 2018).

Furthermore, it was found that the department is unable to carry out this specific duty due to lack of proper institutional arrangement, which has resulted in the department being overburdened with many duties (Arslan and Akun, 2018).

Within the National sphere of government and in terms of water resources management, a CMA is a second tier of the National Sphere. In respect to the study area, Limpopo North West Catchment Management Agency is the CMA and it is currently not functional. The duties of the said CMA are vested to the DWS. Promotion of community participation in the protection of water resources is amongst the duties of a CMA. These duties are thus achieved through community awareness. Section 4.3.3 in chapter four presented results of interviews and survey where a larger number (65%) of research participants indicated that they have not received community awareness in terms of taking care and protecting Hennops River. In general, therefore, it seems that DWS is not coping with ensuring the duties of Limpopo North West Catchment Management Agency are fulfilled.

Even though the South African water policy brings water resources management closer to the people by vesting responsibilities to local government as noted by Van Niekerk and Du Pisani (2006) in the literature review, again, in terms of section 4.3.3, the research finding showed that this is only so in paper. Kayser et.l (2015) suggested that this can be articulated to lack of resources and personnel who are to execute these duties. It is therefore likely that this can be due to lack of funding, which might have resulted in personnel positions remaining as vacant positions. This is supported by Kayser et.al (2015) who also found that scarce financial resources are amongst many other reasons for lack of implementation of various duties. One of the issues that emerges from this finding is pollution of surface water resource by community members due to lack of knowledge, as already seen when solid waste and cut down trees are thrown directly into water resources (Refer to figure 4.16 to 4.18).

Another notable gap on the institutional framework is the reliance of water quality data by the custodian of water resources from the local authority. An implication of this is the possibility of biasness to prevail since DWS as the custodians that is regulating the local authorities, now solely relies on the same local authority (CTMM) in terms of verification of

compliance. Some instances, data has proven inconsistency with various highly polluted monitored points reported as being compliant with the general and special limit (Phosphate graph, figure 4.9). Therefore, various points may also be reported to be compliant with the said limits while they are not. This finding provides further support that the study area is characterized by poor adequate water quality data. This finding agrees with the findings of other studies, in which most of sub-Saharan countries were found to be characterized by poor to inadequate water management information ranging from water quality data to available water resources as reported by Hughes (2019). During the Hennops Catchment Management Forum meeting which the research participated in, CTMM did not present the water quality data and it was also discussed that this is how it has always been. This further supports the idea, by Kayser et.al (2015), that there seem to exist lack of data sharing between ministries, as noted under literature review. It can thus be concluded that departments, which are involved in the water resources management, are not working together.

When we look into governance of surface water resources, in the sub-Saharan African region many researchers have focused their efforts in this particular region than any other region. Tantoh and Simatela (2018) conducted research titled "Complexity and uncertainty in water resource governance in Northwest Cameroon: Reconnoitering the challenges and potential of community-based water resources management", where they found most of the countries does not operate under a system of mandating a single specific government department as a custodian of water resources management. However, the current study found that the South African water management sector operates a little bit different since it has DWS being the custodian of water resources management. An implication of this is that, this set up allows proper coordination of water resources management and accountability directed to a single department.

The NWRS first edition dates back to the year 2004. This document provides framework for protection, use, development, conservation, management and control of water resources. It is now over a decade since the NWRS was promulgated, without review. Over the years, the quality of water resources has greatly changed. The sudden decline in number of fishes along

the River noted under section 4.3.1.2 is an indication of water quality deterioration within Hennops River system. Another possible explanation for this may be inadequate surface water resources management strategy. Therefore, various parts of the NWRS might be irrelevant for managing the ever-changing water systems. Thhe major issue emerging here is the urgent need by government departments to review the NWRS. NWRS is crucial within the water resources management sector to ensure progressive development as it sets precedence for all other water resources management guidelines.

It is interesting to note that in terms of drinking water, the drinking water quality guideline, SANS 241, has been developed and promulgated as a legal requirement. This thus serves as a highlight in development of drinking water quality management legislation. However, the surface water resources still lag behind with no legal water quality guidelines, which are to be used as a tool to enforce compliance.

For many years, the South African approach to manage surface water resources has been the same. The SAWQG: AE remains the only guideline for the aquatic ecosystems with constituents' values marked as the TWQR. The SAWQG: AE has since been the same, with the last edition dating back to 1996 with no revision to date in order to remain relevant to the ever-changing water quality issues. Hennops River has experienced tremendous ecological change between 1996 until now. The DWS should ensure guidelines remain relevant to the ever-changing environment. The guidelines are furthermore not legislated in which case have they been legislated the Department would be legally required to ensure their progressive development. This finding, taken together with those above for the NWRS, it can generally be concluded that DWS has a problem in ensuring progressive development of legislation, strategies and guidelines.

As mentioned in the literature review that pathogens, specifically *E.Coli*, are primary potential water quality impacts. Surprisingly the SAWQG: AE recognizes water resources as complex systems; however, the guidelines do not make provision for the bacteriological constituents. This thus force reliance on the requirements from other legislated documents (The General and special limit authorization) in order to supplement the loophole.

Therefore, through the use of the said limits, one is able to supplement the gap on the SAWQG: AE.

5.3. AUTHOURIZED AND UNAUTHOURIZED COMPLIANCE MANAGEMENT IMPLICATON AND IMPACTS ON THE RIVER

The second research objective was to identify authorized and unauthorized water users within Hennops River and compliance to the WUL and the impacts thereof by the water users. As already indicated under section 4.3.1 above that the regulating authorities were unable to disclose list of water user within Hennops River, therefor the study was unable to achieve the first part of the second research objective. This section will provide compliance management implication and impacts on the River by water users. In doing this, the remaining part of the second research objective will be addressed.

Surface water resources are highly prone to water pollution when compared to its counterpart being ground water resources as noted under literature review. The regulating authorities are therefore charged with responsibility to ensure water resources are not impacted upon negatively by water users. Compliance enforcement is an aspect within surface water resources management. The results of frequency of pollution incidents from interviews and questionnaires corroborates with observation conducted during data collection period. Figures 4.14 to 4.20 corroborates the interviews results as presented in figure 4.12. This also accords to our earlier discussion under section 2.4.1.8 of literature review for the news report by iOL (2019). It is possible therefore, that lack of thorough investigation when pollution incidents are reported and poor compliance monitoring are amongst many reasons of poor surface water resources management. These findings mirror those of Kayser et.al (2015) who also found that inadequate monitoring and compliance enforcement are amongst the major gaps in water resources management.

During observation, evidence of raw sewer as per figure 4.14 was noted as an indication of poor compliance enforcement. If a water treatment plant can impact water resources to this extent, one is safe to conclude that compliance enforcement is at its weakest. Furthermore, DWS has only issued out instruction to COTMM to review water use authorization as per

section 4.3.2. When we look into the requirements of the NWA, in the current status of the Hennops River, chapter 16 which makes provision for interdict or other order by high court, has not been applied as yet. A possible explanation for this could be that intergovernmental cooperation is held supreme. An extent to which intergovernmental cooperation can be extended needs to be looked into so as to ensure water resources are held supreme in terms of their protection.

When we look into water quality results, as presented in figures 4.2 to 4.5, results show high nutrient content. The excess Nitrate in the Hennops River serves as a source of fertilizer for the aquatic plants and algae. This nutrient enrichment is likely to result in excessive algae and plant growth as noted on figure 4.14. Excessive Phosphate in Hennops River speeds up Eutrophication. The observed increase in these Nutrients renders the Hennops prone to eutrophication as a result of excessive Phosphate. These results corroborate the findings of a great deal of the annual report by Department of Water and Sanitation (2016) where they reported that Eutrophication is ranked as one of the highest surface water impacts under section 2.4 of literature review, within the South African context.

5.3.1. NOTABLE WATER IMPACTS

When we look into the water quality analysis data, it is evident that, the water users have impacted upon water quality. In terms of point sources of pollution, the study was unable to identify any of the point sources of pollution, however from the status, it is obvious that WWTP which discharges to the Hennops River, whether upstream or downstream, are the ones contributing to the current presence of raw sewer within Hennops River. This also accords to the Department of Water and Sanitation 2016 yearly report, which indicated Municipal sewer discharge into water resources as a primary dRiver to pollution (DWS, 2016). Again, the declining in number of fishes as noted during research interviews (Refer section 4.3.1.2) are as a result of water quality deterioration, impacted upon by presence of raw sewer in the River.

Solid waste and cut down trees, which are thrown into the River, were also noted during site observation (Refer to figures 4.17 to 4.18). As already noted earlier, community awareness

in this regard might be the reason behind some of the residents within Centurion area not taking care of Hennops River. Foam, was also noted during site observation. Along the areas where there is foam, foul smell was associated with, such foam filled areas. Sadly, the study was unable to identify the source of foam. Agriculture and industries are also listed as urban water pollution. It was anticipated that this urban pollution would be found to be amongst the sources of pollution, surprisingly the study area is not in the vicinity of, agricultural land area, however the foam could be as a result of the industries.

5.4. TOWARDS AN EFFECTIVE SURFACE WATER RESOURCES MANAGEMENT

The above section-highlighted challenges within surfaces water resources management sector, with specific reference to the Hennops River, focusing only on parts that passes through Centurion area. This was done to address the research objectives as contained under section 1.2.1 of chapter one. The current section seeks to contribute to the South African surface water resource management sector. Therefore, this section will address the last research objective.

Chapter 4 section 4.2 presented findings of institutional assessment and legislative framework. From this section, it is evident that South Africa has completely reworked its legislative and institutional framework. The NWA promotes an integrated catchment-based approach to surface water resource management. The establishment of Hennops River catchment management forum meetings serves to adhere to the requirements of the NWA; however, the absence of CMA is a non-compliance to the requirements of the NWA.

The implication of having the CMA duties vested in the DWS as per section 4.2 under chapter 4 is that some, if not all of the duties, may not be executed to their entirety. As already indicated, this may then be articulated to lack or insufficient human resource and financial availability. Taken together with findings presented in sub-section 4.6 regarding community awareness's not being conducted, these results provide evidence as to why the community members are not in knowledge of how to contribute to the resources protection thereby impacting the surface water resources negatively. The mandated institutions should be held

to account when failures and lack of execution of their mandate is noted. The office of the public protector should be in a position to enforce institutions to fully execute their legal mandate.

During literature review, when we looked into the issue of poor cooperative governance and inadequate cross-regulatory interfaces and poor compliance enforcement (DWS, 2016), the two can be said to be intertwined. A limit has to be set in terms of the extent to which intergovernmental cooperation can be extended, to ensure cooperative governance does not weaken compliance.

As note in Table 2.1, local primary driver's remains inadequately addressed by the water resources manager. This finding is no different to the ones highlighted by Hughes (2019) on his research where he also found that primary drivers of water quality impacts for Malawi region, remains inadequately addressed. When we further look into the current study area, this also accords to the water quality data request made to the regulating authorities, which then were unable to make such data available to the study.

Management approach employed in managing surface water resources across the globe vary, however there are approaches which are similar, as noted under literature review, for example the water quality monitoring programme. Most importantly, the current study contributed knowledge in the research body regarding gaps which are currently existing in policies, strategies and SAWQ:AE for the protection of surface water resources.

In order to effectively manage surface water resources, the following water resources management structure, in addition to the current surface water resources management framework, is proposed: quality management sub-section office be established within each institution, per-department, which will be responsible for document control. This department can thus report directly to the office of the public protector. This will ensure progressive development of vital documents within each mandated institution. Water resources management sector will therefore move towards an improved surface water resources management.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1. INTRODUCTION

This study has evaluated the effectiveness of the current Water Resource Management Approaches in Maintaining the Requirements of the South African Guidelines for Aquatic Ecosystem for Hennops River, focusing only on parts that passes through Centurion are in South Africa. This chapter is dedicated to summarsing key findings of the study. As well as providing recommendation. Suggestion on future research will also be made under this Chapter.

6.2. SUMMARY OF KEY FINDINGS

The research has extended knowledge in terms of management approaches employed for the protection of surface water resources, Hennops River, in order to comply with the requirements of the SAWQG: AE. It was found that legislation lags behind in the protection of surface water resources. Whilst the SANS 241 supports the drinking water resources management approach, the surface water resources for aquatic ecosystems is lagging behind. The second major fining was that of WQM pogramme, which is deemed as a critical tool in the water resources management, has been discontinued for DWS monitored points. This was viewed as one of those aspects, which does not support the compliance to the SAWQG: AE.

The most obvious finding to emerge from the current study is that the water users of Hennops River has inevitably impacted the quality of water within Hennops River. The study has found that generally the quality of water within the stream is non-compliant with the GL and SL which is an indication of failure to comply with the said guidelines. The noted visually unappealing Hennops River noted during site inspection and foul smell noted, provided further evidence that Hennops River is polluted. Since the water quality results showed excess Nutrient at point of discharge by the Sunderland Ridge WWTP, it is concluded that the Sunderland Ridge WWTP is not compliant with the GL and SL. The study showed that

Hennops River is at a risk of direct pollution by residents and all other authorized water users, with associated lack of River health community-based awareness. Lastly and most critical, the un-operational newly established CMA which hinders full execution of the CMA duties.

6.3. RECOMMENDATIONS

Based on the above discussion and other chapters, it is recommended that the DWS should ensure progressive development of the NWRS and the SAWQG: AE which will thus ensure that these documents remain relevant in addressing water management issues. Secondly, the establishment of the Limpopo CMA has not yet seen operation, therefore there is a need to FastTrack operation of this CMA. The bacteriological constituents should be included in the SAWQG: AE as this renders reliance on the General and special limit. Furthermore, there is a need for development and implementation of SANS for aquatic ecosystem. This is due to the fact that SANS is a legal requirement and therefore water user will be compelled to comply to it, making it easier for regulating authorities to enforce it.

There is a great need to strengthen community awareness in terms of surface water resources protection by both DWS and COTMM. DWS should set the CEV at the point of discharge by the Sunderland ridge waste water treatment plant. Since the stream is highly polluted, DWS should set the AEV which should be used to identify and implement migratory measure. However, the set AEV should not be used for setting the water quality requirements for aquatic ecosystems. Government departments should strengthen compliance enforcement by the WWTP and all unauthorized water users. Lastly, even though the issue of financial availability is unavoidable, DWS should be provided with sufficient budget that will ensure that WQM programs are not affected. On a political note, since most budget is allocated to the department that creates job opportunities, rehabilitation of Hennops River will create more job through the Expanded Public Works Projects.

6.4. FUTURE RESEARCH

Since the study only focused at the Hennops River, only parts which passes through Centurion area, a broader perspective will ensure that all aspect of a catchment in term of management approaches employed in achieving the objectives of the SAWQG:AE will yield interesting results. Secondly the current research could be applied to other catchment, whether individually or collectively or comparison of two or more catchment, either focusing on any of the South Africa water Quality Guidelines. More research is needed on effective management approaches on surface water resources. Research on application of quality management systems, focusing more on document control, in terms of water resources management, which will ensure progressive development of all documents, might also produce interesting results. Lastly, the feasibility study of the office of Public protector to monitor the mandated institutions in terms of water resources management in their full execution of their legal requirement could produce useful results.

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8. APPENDIX

APPENDIX A

Email sent to Ward 78 Councilor authorization for authorization to proceed with interview of community members

Good day

I am student at the University of Witwatersrand doing an Msc in Environmental Sciences. As part of my studies, I am conducting a research in "Evaluating the effectiveness of the current water resources management approaches in maintaining the requirements of South African guidelines for aquatic ecosystem: The case of Hennops River". As part of my data collection instruments, I would like to conduct an interview with community members within Centurion area. Kindly let me know if I can proceed.

Attached is a copy of interview guide and questionnaire that I will use.

Your response is highly valued. Thank

Kind regards
A.Sadiki
721317@studnts.wits.ac.za

APPENDIX B

Email sent to Hennops River forum member asking for their involvement in the study

Morning all

Please receive attached questionnaire as indicated during yesterday's Hennops River forum.

Kindly fill in questions which you are comfortable with answering. I would also like to request water quality data from January 2017 till now and register of authourised and unauthourised water users.

I will appreciate speedy response as this will ensure that I process all data collected timeously.

Assistance is highly appreciated.

A.Sadiki

721317@studnts.wits.ac.za

APPENDIX C

Emails sent to Hennops River forum member asking for their involvement in the study

Good day

I am student at the University of Witwatersrand doing an Msc in Environmental Sciences. As part of my studies, I am conducting a research in "Evaluating the effectiveness of the current water resources management approaches in maintaining the requirements of South African guidelines for aquatic ecosystem: The case of Hennops River". As part of my data collection instruments, I would like to conduct an interview at the date and time convenient to you. If you are unable to meet for interview, kindly receive attached questionnaire and supporting documents.

Please fill it in and forward it back to me.

Your response is highly valued. Thank

Kind regards
A.Sadiki
721317@studnts.wits.ac.za

APPENDIX D

Participant information sheet, consent form, Interview guide, questionnaire

Participant information sheet

Evaluating the effectiveness of the current water resources management approaches in maintaining the requirements of South African guidelines for aquatic ecosystem: The case of Hennops River

Participant Information Sheet

Dear Sir / Madam

My name is Andronica Sadiki. I am currently pursuing a Master's degree in Environmental Sciences from the School of Animal, Plant and Environmental Sciences at the University of Witwatersrand. As part of the degree, I am expected to conduct a research and my research is entitled "**Evaluating the effectiveness of the current water resources management approaches in maintaining the requirements of South African guidelines for aquatic ecosystem: The case of Hennops River."**

I would like to conduct an interview with you at a time and a place of your convenience on this topic. This interview will take about 20 minutes to complete. There are not benefits to you if you wish to participate as well as no disadvantage if you wish not to participate in this interview, you may also withdraw at any time. During the interview, I may ask to record the interview and any discretion will be highly respected. Your name and any of your personal information will not be quoted in any of the research documents if you wish to remain anonymous.

Your cooperation and sincere response to the questions would be greatly appreciated.

Yours faithfully,
RESEARCHER

Andronica Sadiki
721317@students.wits.ac.za
Cell: 0724659016

SUPERVISOR
Prof Mulala Danny Simatele
Mulala.Simatele@wits.ac.za
Cell: 0833836884

Consent form

Evaluating the effectiveness of the current water resources management approaches in maintaining the requirements of South African guidelines for aquatic ecosystem: The case of Hennops River

Formal consent form

Dear Participant

*The aim of this questionnaire is to understand how water resources management processes can ensure that legally required water quality is maintained in surface water resources by "**Evaluating the effectiveness of the current water resources management approaches in maintaining the requirements of South African guidelines for aquatic ecosystem: The case of Hennops River Africa.".** The study guarantees confidentiality and anonymity. Your name and any of your personal information which can make your identity known, will not be published or use any words that may expose your identity, if you wish to stay anonymous.*

[X] **Please indicate with "X" where appropriate**

Do you agree to participate in this interview for the research project?

[ ] Yes, I agree

[ ] No. I do not agree

Do you agree to this interview to be audio recorded?

[ ] Yes, I agree

[ ] No. I do not agree

Do you wish for your interview to remain anonymous and for your name to be anonymised in the project report?

[ ] Yes, I agree

[ ] No. I do not agree

…… ……..

Participant Signature Date

Interview guide: Expert

Evaluating the effectiveness of the current water resources management approaches in maintaining the requirements of South African guidelines for aquatic ecosystem: The case of Hennops River Africa.

Interview guide

Title :……

1. What do you think the current status of surface water resource is, in particular City of Tshwane metropolitan Municipality?

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2. In your opinion, what do you think is the contributing factors to the current status of surface water resources?

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3. Do you think the current institutional framework support/promote the preamble of the National Water Act?

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……

4. What aspects of the current institutional framework do you think support/promote the preamble of the National Water Act?

……

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……

……

Thank you for your co-operation.

Questionnaire: NGO and I&AP

Evaluating the effectiveness of the current water resources management approaches in maintaining the requirements of South African guidelines for aquatic ecosystem: The case of Hennops River Africa..

Questionnaire

Questionnaires for NGO's

Title :……

5. What do you think the current status of surface water resource is, in particular City of Tshwane metropolitan Municipality?

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……
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……
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6. In your opinion, what do you think is the contributing factors to the current status of surface water resources?

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7. Do you think the current institutional framework support/promote the preamble of the National Water Act?

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8. What types of water resources management measures should be employed in surface water resources to ensure compliance with the water quality guidelines?

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Thank you for your co-operation.

Questionnaire: Residents

Evaluating the effectiveness of the current water resources management approaches in maintaining the requirements of South African guidelines for aquatic ecosystem: The case of Hennops River Africa.

Questionnaire

Questionnaires for local residents, nearby Hennops River

Name and Surname:……
Address :……
……
……

9. What types of activities do you use the Hennops River for?

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10. In terms of visual appeal, how is the River when you access it?

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11. Has there been any community awareness conducted by government officials in terms of taking care of River?

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12. If Yes, how often?

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13. Was there awareness effective?

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14. In terms of reported pollution incident, how long does the municipality take to attend to the incidents?

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15. How frequent does pollution incident take place?

……

……

……

……

……

16. Have you, in the past noticed activities taking place in the stream which you may suspect to be unauthourised?

……

……

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……

……

17. If yes, please elaborate what you witnessed?

……

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……

18. Do you think the local authority is doing a great job in taking care of the stream?

Insufficient ☐ Sufficient ☐ Not sure ☐

Please elaborate:

……

……

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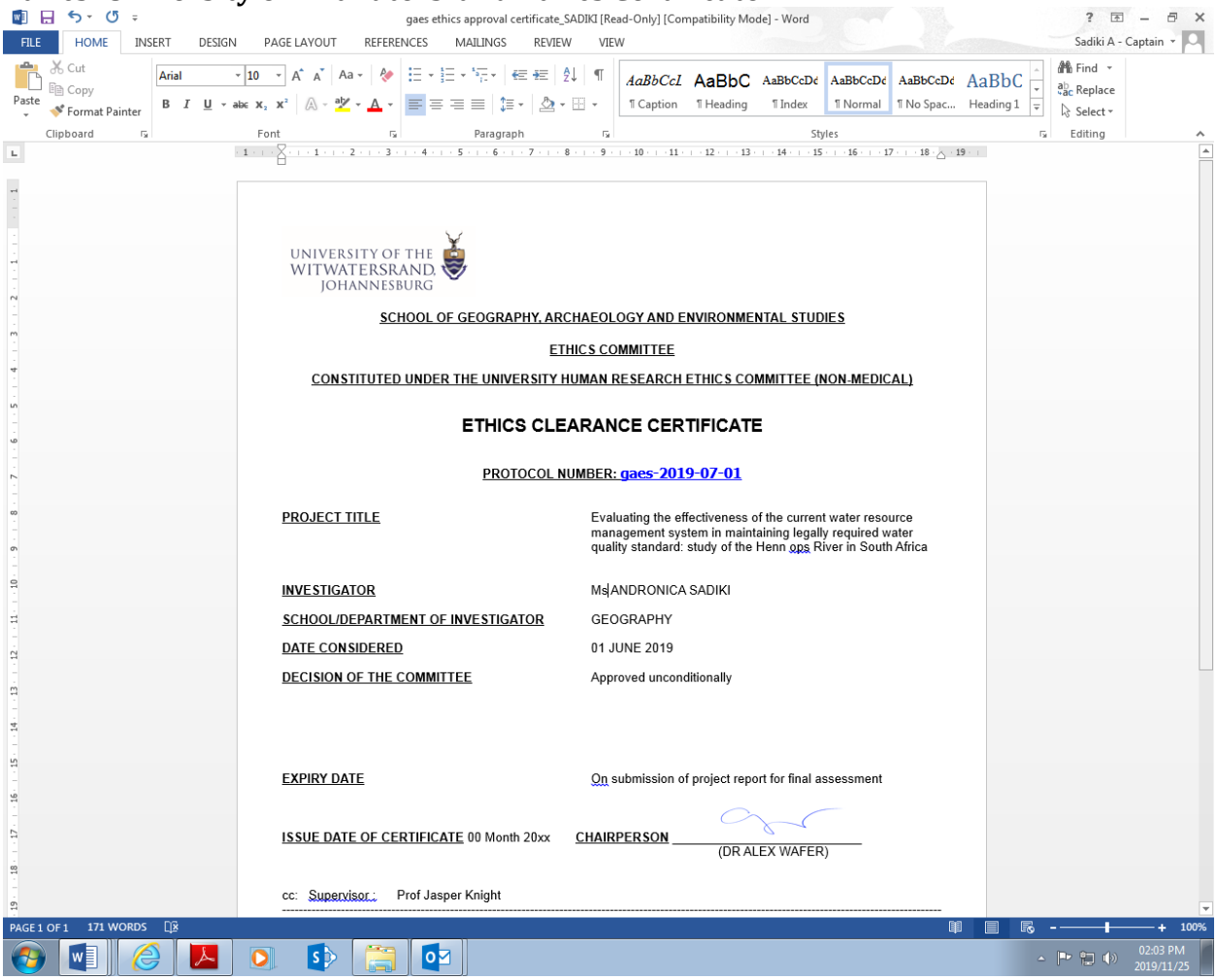
……

……

Thank you for your co-operation.

APPENDIX E
Ethics: University of Witwatersrand Ethics Certificate



gaes ethics approval certificate_SADIKI [Read-Only] [Compatibility Mode] - Word

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

SCHOOL OF GEOGRAPHY, ARCHAEOLOGY AND ENVIRONMENTAL STUDIES

ETHICS COMMITTEE

CONSTITUTED UNDER THE UNIVERSITY HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)

ETHICS CLEARANCE CERTIFICATE

PROTOCOL NUMBER: gaes-2019-07-01

PROJECT TITLE	Evaluating the effectiveness of the current water resource management system in maintaining legally required water quality standard: study of the Henn ops River in South Africa
INVESTIGATOR	Ms ANDRONICA SADIKI
SCHOOL/DEPARTMENT OF INVESTIGATOR	GEOGRAPHY
DATE CONSIDERED	01 JUNE 2019
DECISION OF THE COMMITTEE	Approved unconditionally
EXPIRY DATE	On submission of project report for final assessment

ISSUE DATE OF CERTIFICATE 00 Month 20xx CHAIRPERSON _____ (DR ALEX WAFER)

cc: Supervisor : Prof Jasper Knight

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ANNEXURE F
Primary field data

Questionnaires: NGO's and I&AP

1. **What do you think the current status of surface water resource is, in particular City of Tshwane Metropolitan Municipality?**

P1: "*Tragic state, Human rights violation through Tshwane has E.coli count of over 1 million. River severely polluted by sewerage, industrial waste, plastic, building rubbles etc*"

P2: "*Extremely polluted. The main River through Tshwane, the entire River has E.oli count of over 1 million. This is an extreme health hazard. The stream and the River are full of solid waste, building rubble and plastic*"

P4: "It is not complying with the standard and that might be attributed to various sources of point and non-point pollution"

2. **In your opinion, what do you think is the contributing factors to the current status of surface water resources?**

P1: "Littering, lack of education on importance of Rivers, overcapacity and lack of operational maintenance of waste water treatment plants, abuse of Rivers"

P2: *Illegal dumping, misuse, overcapacity and vandalism of the sewer network*"

P4: *"Firstly is the inability to do proper monitoring of pollution sources and availability of funds to conduct proper monitoring including regulating all uses of the environment in the catchment*"

3. **Do you think the current institutional framework support/promote the preamble of the National Water Act?**

P1: "*This needs to be managed and enforced to protect the River*"

P2: *did not answer the question*

P4: *"to a certain extent it does. Water availability is a challenge including water allocation. Redressing past racial and gender imbalance on use of water is still a challenge to address"*

4. **What types of water resources management measures should be employed in surface water resources to ensure compliance with water quality guidelines?**

P1: "*Education. Training and implementation of clean-up campaigns at municipal level managed and effectively implemented*"

P2: "*Improvement of waste collection and sanitation networks. A very important aspect is enforcement of municipal by-laws to stop illegal dumping of rubbles. Illegal dumping of household waste, misuse of the sewer network, vandalism of the sewer network*"

Interview: Expert

1. What do you think the current status of surface water resource is, in particular City of Tshwane metropolitan Municipality?

P3: *"The current surface water resources does not look good"*

2. In your opinion, what do you think is the contributing factors to the current status of surface water resources?

P3: *"Waste water treatment plants not meeting capacity. Only one WWTP that meets the requirements, resulting in others discharging pollutants to the stream. Infrastructure does not support the growing demand"*

3. Do you think the current institutional framework support/promote the preamble of the National Water Act?

P3: *"Previously it used to support it, the likes of catchment management meetings no longer taking place"*

4. What types of water resources management measures should be employed in surface water resources to ensure compliance with the water quality guidelines?

P3: *"Continuous water resources monitoring, compliance enforcement to be in place and avoid misuse of stream"*

Interviews: Residents

1. Types of activities

Viewing

Rituals, fishing, baptism, drinking, washing

Rituals, criminal activities

Rituals

Rituals, fishing

Nothing

Nothing

Nothing

Nothing

Nothing

Washing

Work

Nothing

Nothing

Nothing

Nothing

Rituals, fishing, baptism

Activities	Activities taking place at Hennops River
Rituals	24
Baptism	10
Fishing	14
Washing	9
Nothing	23

2. Visual appeal

Sometimes clean sometimes dirty

Feces and foam

Not appealing

Sometimes clean sometimes dirty

Dirty

Not appealing, foul smell

Not appealing, dirty, foul smell

Feces and foam

Dirty

Feces and foam

Dirty

Not appealing, dirty

Sometimes clean sometimes dirty

Sometimes clean sometimes dirty

Sometimes clean sometimes dirty

Some parts clean, dirty

% of respondents	Visual appeal of the Hennops River

Feces and foam	14
Not appealing	14
Dirty	38
Sometimes clean sometimes dirty	24
Foul smell	10

3. Community awareness conducted

Yes

No

Yes

No

No

No

Yes

No

No

No

No

Yes

Not sure

No

Not sure

No

No

% of respondents	community awareness in terms of taking care of River conducted
Yes	23
No	65
Not sure	12

4. Frequency/interval of awareness

Once in a while

Once in a while

5. Was awareness effective

No

No

Yes

No

yes

6. Mitigation of pollution incidents

Same day

Never

Never

Never

Never

Take long

Never

Never

Never

Take long

Take long

Take long

Take long

Never

Never

% of respondents	How long does it take for pollution incidents to be attended to?
Same day	7
Never	60
Takes long	33

7. Occurrence of pollution incidents

Daily

Daily

Daily

More often

During rainy seasons

Once in a while

During dry seasons

Daily

Daily

Daily

Daily

Daily

Daily

More often

More often

Daily

More often

Daily

% of respondents	Frequency of pollution incidents
Daily	65
More often	23
During rainy season	6
During dry seasons	6

8. Witnessed unauthorized activities

Not sure

No

No

No

No

No

No

No

No

No

No

No

No

Yes

No

No

9. Types of unauthorized activities

Waste disposal

10. Local authority taking care of Rivers

14: Insufficient

3: Sufficient

% of respondents	**Is local authority going great job in taking care Hennops River?**
Insufficient	82
Sufficient	18

APPENDIX G
Raw water quality data

Water monitoring point-195445: Centurion at Centurion Lake

mon_feat	date_time	sample_b	institutior	preservati	Ca_Diss_V	Cl_Diss_W	DMS_Tot_	EC_Phys_V	F_Diss_W	K_Diss_W	KJEL_N_To	Mg_Diss_V	Na_Diss_V	NH4_N_Di	NO3_NO2	P_Tot_Wa	pH_Diss_V	PO4_P_Di	Si_Diss_W	SO4_Diss_
195445	2017/11/27 12:25	0	DWS-RQIS	HGCL2	33	55.8	412.106	59.6	0.195	10.6	2.144	14.6	65.7	0.05	8.87	0.944	8.5	0.888	6.1	58.6
195445	2017/12/11 13:10	0	DWS-RQIS	HGCL2	34.8	#N/A	#N/A	68.7	0.233	6.3	#N/A	8.1	#N/A	0.05	4.829	#N/A	8.3	0.192	#N/A	#N/A
195445	2018/01/22 12:45	0	DWS-RQIS	HGCL2	34.8	80	528.558	74.9	0.271	12.2	#N/A	14.8	84	0.888	26.701	#N/A	7.5	1.644	8.1	60.2
195445	2018/02/05 12:20	0	DWS-RQIS	HGCL2	42.8	220.7	657.015	106.2	0.261	9.4	6.359	12	149.5	4.156	1.23	0.381	8.4	0.174	5.3	56.3
195445	2018/02/19 11:00	0	DWS-RQIS	HGCL2	43.2	125.9	540.933	87.2	0.195	11.4	2.032	14.2	109.2	0.05	9.58	#N/A	7.3	1.361	6.9	59
195445	2018/03/05 12:30	0	DWS-RQIS	HGCL2	37.8	63	526.688	74.9	0.315	15.2	1.554	15.7	87.7	0.1	24.329	4.669	8	3.751	9.8	68.4
195445	2018/03/19 11:56	0	DWS-RQIS	HGCL2	#N/A	#N/A	#N/A	50.4	0.265	9	#N/A	#N/A	47.6	0.05	7.638	0.695	8.4	0.359	#N/A	#N/A
195445	2018/04/03 12:30	0	DWS-RQIS	HGCL2	#N/A	#N/A	#N/A	55.2	0.192	9.5	#N/A	#N/A	48.2	4.739	1.443	0.58	8.4	0.315	#N/A	#N/A
195445	2018/04/16 12:20	0	DWS-RQIS	HGCL2	#N/A	#N/A	#N/A	107.5	0.267	12	#N/A	#N/A	146.7	6.588	0.759	0.885	8.1	0.565	#N/A	#N/A
195445	2018/05/14 12:05	0	DWS-RQIS	HGCL2	#N/A	#N/A	#N/A	59	0.207	11	#N/A	#N/A	63	0.05	18.079	1.3	8	1.057	#N/A	#N/A
195445	2018/05/28 12:07	0	DWS-RQIS	HGCL2	#N/A	56.494	#N/A	62.1	0.128	#N/A	2.707	#N/A	#N/A	0.05	22.384	1.736	7.835	1.264	7.595	56.317
195445	2018/06/11 12:20	0	DWS-RQIS	HGCL2	#N/A	67.112	#N/A	63.8	0.133	#N/A	0.963	#N/A	#N/A	0.05	16.765	1.55	7.68	1.161	7.566	59.24
195445	2018/06/25 11:55	0	DWS-RQIS	HGCL2	#N/A	50.861	#N/A	67.2	0.171	#N/A	1.245	#N/A	#N/A	0.05	26.08	4.3	8.155	3.626	7.553	57.628

Water monitoring point-195444: centurion-at Road Bridge over (Sesmylspruit) at Centurion dam inlet

mon_feat	date_time	sample_b	institutior	preservati	Ca_Diss_V	Cl_Diss_W	DMS_Tot_	EC_Phys_V	F_Diss_W	K_Diss_W	KJEL_N_To	Mg_Diss_V	Na_Diss_V	NH4_N_Di	NO3_NO2	P_Tot_Wa	pH_Diss_V	PO4_P_Di	Si_Diss_W	SO4_Diss_	TAL_Diss_
195444	2017/11/27 12:00	0	DWS-RQIS	HGCL2	34.1	57.8	415.651	60.4	0.181	10.7	2.194	14.3	66.5	0.05	9.516	1.005	8.3	0.758	6.9	59.9	104.7
195444	2017/12/11 13:00	0	DWS-RQIS	HGCL2	35.4	148.6	426.277	75.9	0.174	6.3	3.368	8.1	93.1	0.05	3.513	0.687	8.2	0.142	4.8	39.3	65
195444	2018/01/22 12:26	0	DWS-RQIS	HGCL2	34.5	#N/A	#N/A	78.6	0.236	11.4	18.226	13.7	#N/A	0.05	19.333	1.582	7.6	1.439	8.1	59.2	102.2
195444	2018/02/05 12:05	0	DWS-RQIS	HGCL2	38.4	197.4	618.32	96.8	0.366	10.1	5.995	10.9	130.2	4.347	1.539	0.373	8.2	0.193	5.3	56.4	132.5
195444	2018/02/19 10:45	0	DWS-RQIS	HGCL2	39.8	#N/A	#N/A	87.2	0.205	12.6	#N/A	14.8	106	9.261	0.421	0.969	8.2	0.691	#N/A	#N/A	194.4
195444	2018/03/05 12:18	0	DWS-RQIS	HGCL2	37.3	61.4	511.288	73.8	0.253	14.9	1.175	15.4	87.8	0.1	22.632	4.337	8	3.266	9.6	67.1	95.8
195444	2018/03/19 11:45	0	DWS-RQIS	HGCL2	#N/A	#N/A	#N/A	50.1	0.189	9.1	#N/A	#N/A	48.5	0.05	8.531	0.737	8.4	0.533	#N/A	#N/A	104.9
195444	2018/04/03 12:10	0	DWS-RQIS	HGCL2	#N/A	#N/A	#N/A	52.7	0.17	9.5	#N/A	#N/A	48.7	0.05	8.98	0.646	7.5	0.355	#N/A	#N/A	115.6
195444	2018/04/16 12:05	0	DWS-RQIS	HGCL2	#N/A	#N/A	#N/A	96.9	0.252	11.7	#N/A	#N/A	135	0.05	8.464	0.853	7.5	0.466	#N/A	#N/A	150.7
195444	2018/05/14 11:50	0	DWS-RQIS	HGCL2	#N/A	#N/A	#N/A	60.3	0.188	11.4	#N/A	#N/A	64.4	0.05	17.894	1.137	7.9	1.02	#N/A	#N/A	89.7
195444	2018/05/28 11:54	0	DWS-RQIS	HGCL2	#N/A	64.943	#N/A	62.7	0.148	#N/A	2.47	#N/A	#N/A	0.05	23.552	2.092	8.127	1.357	7.652	56.932	100.596
195444	2018/06/11 12:00	0	DWS-RQIS	HGCL2	#N/A	53.383	#N/A	62.9	0.198	#N/A	#N/A	#N/A	#N/A	0.05	20.418	1.609	8.124	1.346	7.632	61.812	95.73

Water monitoring point-195443: Centurion at Road bridge over Hennops (Sesmylspruit) at Centurion lake inlet

mon_feat	date_time	sample_b	institution	preservati	Ca_Diss_W	Cl_Diss_W	DMS_Tot_	EC_Phys_W	F_Diss_Wa	K_Diss_W	KJEL_N_To	Mg_Diss_W	Na_Diss_W	NH4_N_Di	NO3_NO2	P_Tot_Wa	pH_Diss_W	PO4_P_Di	Si_Diss_W	SO4_Diss_	TAL_Diss_
195443	2017/11/27 11:45	0	DWS-RQIS	HGCL2	32.5	56.8	414.75	59.6	0.212	10.7	3.059	14.2	65.6	0.05	9.545	0.896	8.4	0.644	6.4	58.4	108.3
195443	2017/12/11 12:30	0	DWS-RQIS	HGCL2	36.1	#N/A	#N/A	74.8	0.23	6.6	#N/A	8.5	#N/A	0.05	4.15	#N/A	8.1	0.159	#N/A	#N/A	68.1
195443	2018/01/22 12:06	0	DWS-RQIS	HGCL2	35.9	81.2	536.531	74.5	0.28	13	14.11	14.7	86.2	0.05	25.143	1.433	7.9	1.242	8.1	61.2	105.7
195443	2018/02/05 11:50	0	DWS-RQIS	HGCL2	41.4	255.5	663.414	109	0.316	10.1	2.795	11.8	154.8	0.05	6.665	0.436	8.2	0.17	5.3	57.6	83.5
195443	2018/02/19 10:27	0	DWS-RQIS	HGCL2	39.7	#N/A	#N/A	89.4	0.18	13	#N/A	15.5	108.5	9.947	0.567	0.999	8.3	0.969	#N/A	#N/A	201.9
195443	2018/03/05 12:00	0	DWS-RQIS	HGCL2	38	63.2	523.525	75.2	0.266	15.5	3.556	15.7	89.7	0.1	18.241	4.44	7.1	3.968	9.7	67.9	115
195443	2018/03/19 11:32	0	DWS-RQIS	HGCL2	#N/A	#N/A	#N/A	50.5	0.238	8.9	#N/A	#N/A	46.1	0.05	8.878	1.338	7.9	0.616	#N/A	#N/A	111.1
195443	2018/04/03 11:50	0	DWS-RQIS	HGCL2	#N/A	#N/A	#N/A	55	0.19	9.6	#N/A	#N/A	48.8	3.522	1.521	0.649	8.1	0.297	#N/A	#N/A	164.5
195443	2018/04/16 11:45	0	DWS-RQIS	HGCL2	#N/A	213.64	#N/A	108.7	0.086	#N/A	3.19	#N/A	#N/A	0.05	8.974	0.897	7.3	0.399	6.505	56.931	127.331
195443	2018/05/14 11:35	0	DWS-RQIS	HGCL2	#N/A	#N/A	#N/A	59.7	0.212	11.2	#N/A	#N/A	66	0.05	17.329	1.221	8.1	1.026	#N/A	#N/A	110.2
195443	2018/05/28 11:35	0	DWS-RQIS	HGCL2	#N/A	60.703	#N/A	61.7	0.16	#N/A	2.305	#N/A	#N/A	0.05	21.087	1.819	7.861	1.305	7.479	55.684	107.357
195443	2018/06/11 11:45	0	DWS-RQIS	HGCL2	#N/A	56.262	#N/A	62.6	0.199	#N/A	0.1	#N/A	#N/A	0.05	17.963	1.604	7.823	1.317	7.666	57.463	135.942
195443	2018/06/25 11:15	0	DWS-RQIS	HGCL2	#N/A	50.55	#N/A	66.5	0.17	#N/A	0.1	#N/A	#N/A	0.05	25.282	4.375	7.667	3.782	7.269	57.971	91.528

Water monitoring point-190454: Sunderland ridge WWTP final effluent discharge on canal to Hennops River

YEAR	NO3_NO2	pH_Diss_W	PO4_P_Diss_Water
2017 Jan	37.505	7.4	1.246
2017 Feb	29.342	6.8	1.054
2017 Mar	29.844	7.8	2.134
2017 Jun	38.335	6.6	4.309
2017 Jul	37.698	5.9	3.031
2017 Nov	17.328	7.2	1.811

APPENDIX H
SAWQG: AE water quality constituents

TWQR and Criteria	Aluminium concentration (µg/·)	
	pH<6.5	pH6>6.5
TWQR	·5	·10
CEV	10	20
AEV	100	150

Table 2.1: Acid soluble Aluminium

TWQR and criteria	Un-ionised Ammonia concentration (· G N/ ·)
TWQR	· 7
CEV	15
AEV	100

Table 2.2: Un-ionised Ammonia

TWQR and criteria	Arsenic concentration (µg/·)
TWQR	· 10
CEV	20
AEV	130

Table 2.3: Arsenic

TWQR and criteria	Atrazine concentration (µg/·)
TWQR	· 10
CEV	19
AEV	100 *20 (For protection of plants)

Table 2.4: Atrazine

TWQR and Criteria	Cadmium concentration (µg/·)					Cadmium concentration ($CaCo_3$·)			
	<60 (Soft)	60-119 (Medium)	120-180 (Hard)	>180 (Very hard)		<60 (Soft)	60-119 (Medium)	120-180 (Hard)	>180 (Very hard)
TWQR	·0.15	·0.25	·0.35	·0.40		·0.07	·0.1	·0.15	·0.017
CEV	0.3	0.5	0.7	0.8		0.15	0.19	0.29	0.34

AEV	3	6	10	13		1.8	2.8	5.1	6.2

Table 2.5: Cadmium

TWQR and criteria	Chlorine concentration (µg/·)
TWQR	· 0.2
CEV	0.35
AEV	5 of plants)

Table 2.6: Residual Chlorine

TWQR and criteria	Chromium (VI) concentration (µg/·)	Chromium (III) concentration (µg/·)
TWQR	·7	·12
CEV	14	24
AEV	200	340

Table 2.7: Dissolved Chromium

TWQR and Criteria	Copper concentration (µg/·)			
	<60 (Soft)	60-119 (Medium)	120-180 (Hard)	>180 (Very hard)
TWQR	·0.3	·0.8	·1.2	·1.4
CEV	0.53	1.5	2.4	2.8
AEV	1.6	4.6	7.5	12

Table 2.8: Dissolved copper

TWQR and criteria	Free Cyanide concentration (µg/·)
TWQR	· 1
CEV	4
AEV	110

Table 2.9: Free Cyanide

TWQR and criteria	Endosulfan concentration (µg/·)
TWQR	·0.01
CEV	0.02

AEV	0.2

Table 2.11: Endosulfan

TWQR and criteria	Fluoride concentration (µg/·)
TWQR	·750
CEV	1500
AEV	2540

Table 2.12: Dissolved flouride

TWQR
The iron concentration should not be allowed to vary by more than 10% of the background dissolved iron concentration for a particular site or case, at a specific time.

Table 2.15: Iron

TWAR and criteria	Lead concentration (µg/·)			
	<60 (Soft)	60-119 (Medium)	120-180 (Hard)	>180 (Very hard)
TWQR	·0.2	·0.5	·1.0	·1.2
CEV	0.5	1.0	2.0	2.4
AEV	4	7.0	13	16

Table 2.13: Dissolved Lead at different water hardness (mg $CaCo_3$/·)

The table below gives the factors by which the threshold concentration of lead must be multiplied to determine concentrations of equal toxicity at progressively lower dissolved oxygen concentrations

Dissolved oxygen (% of saturation)	100	80	60	40
Factor	1.0	0.95	0.85	071

Table 2.14: Dissolved Lead at different water hardness (mg $CaCo_3$/·)

TWAR and criteria	Manganese concentration (µg/·)
TWQR	·180
CEV	370
AEV	1300

Table 2.15: Dissolved manganese

TWQR and criteria	Mercury concentration (µg/·)
TWQR	·0.04
CEV	0.08
AEV	1.7

Table 2.16: Total Mercury

Water Resource	TWQR
All surface waters	• Inorganic Nitrogen concentration should not be changed by more than 15% from that of water body under local un-impacted conditions at any time of the year; and • The trophic status of the water body should not increase above its present level, though a decrease in trophic streams is permissible; and • The amplitude and frequency of natural cycles in inorganic nitrogen concentration should not be changed

Table 2.17: Nitrogen (Inorganic)

TWQR and criteria	Selenium concentration (µg/·)
TQWR	·2
CEV	5
AEV	30

Table 2.21: Total Selenium

TWQR and criteria	Total phenol concentration (µg/·)
TWQR	·30
CEV	30
AEV	500

Table 2.19: Phenol

TWQR and criteria	Zinc concentration (µg/·)
TQWR	·2
CEV	3.6
AEV	36

Table 2.25: Dissolved Zinc

APPENDIX I

Figure 4.4: Water monitoring point-190454: Sunderland ridge WWTP final effluent discharge on canal to Hennops River
(Google earth, 2019)

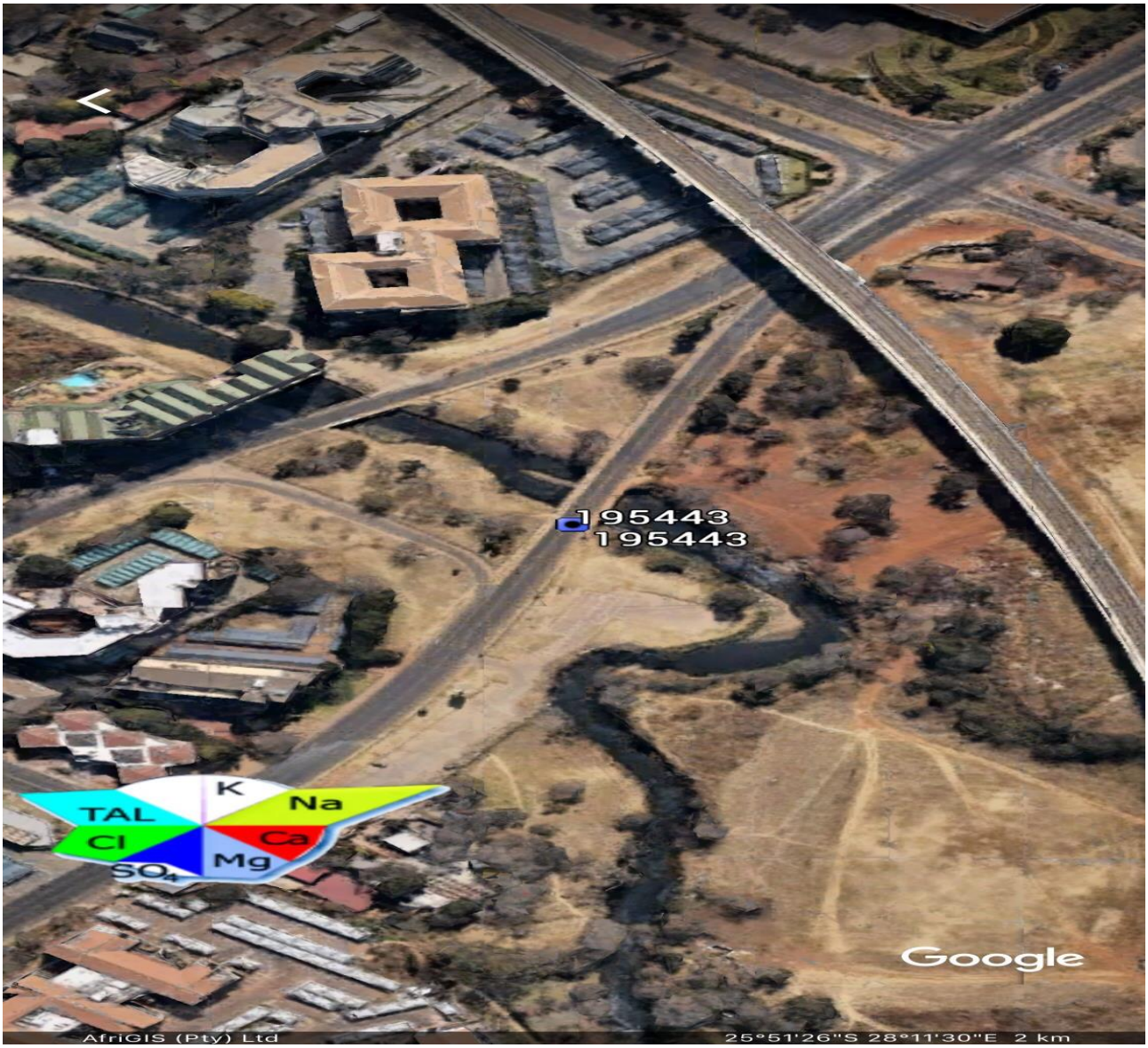

Figure 4.2: Water monitoring point-195443: Centurion at Road bridge over Hennops (Sesmylspruit) at Centurion lake inlet
(Google earth, 2019)

Figure 4.3: Water monitoring point-195444: centurion-at Road Bridge over (Sesmylspruit) at Centurion dam inlet
(Google earth, 2019)