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REPUBLIC OF SOUTH AFRICA

SITUATION ASSESSMENT AND GAP ANALYIS REPORT

PROJECT NO: RDM/00/IHS/SDC/0320.

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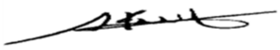

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EXECUTIVE SUMMARY

The word ‘eutrophic’ comes from the Greek word ‘*eutrophos’* meaning well-fed (OECD, 1982). Department of Water Affairs (DWA) (1986), supported by Rossouw *et al*. (2008) described eutrophication as the enrichment of water with plant nutrients which promotes excessive growth of algae and aquatic macrophytes. Whereas, van Ginkel (2011) described eutrophication as a process of nutrient enrichment and the associated excessive plant growth such as algae and macrophytes in water bodies, which can be seen as either a natural aging process in the aquatic ecosystems or accelerated by human impacts.

The two main eutrophication sources are point and diffuse (also known as non-point) sources of pollution. The point sources are associated with pipeline discharge of effluent from facilities such as Waste Water Treatment Works (WWTWs) and industrial discharges; whereas diffuse sources of pollution emanate mainly from the atmospheric deposition process (nutrients leaching from certain rocks and soils), settlements (urban, peri-urban and informal) and agricultural run-off (DWA, 1986).

Eutrophication was recognized as a threat to South African surface waters almost seven (7) decades ago and the first impacts thereof became apparent in the 1950s and reaching problematic levels in the 1960s (Walmsley and Butty, 1980; Zohary *et al.,* 1988; and van Ginkel, 2011).

Since the early 1990s, water pollution has worsened in almost all rivers in Africa, Asia and Latin America. The deterioration of water quality is expected to further escalate over the next decades and this will increase threats to human health (U.S EPA, 1998). In South African reservoirs as well, as supported by Rossouw et al. (2008) it was found that the extent of eutrophication had increased since the problem was first identified in the 1970s.

Eutrophication leads to a progressive deterioration of water quality and other undesirable changes that interfere with water use, by reducing its suitability for use (DWA, 1986). It constitutes a major threat to the provision of raw potable and irrigation water in South Africa (SA), being largely dependent on impounded water for water supply (Harding, 2008). Poor water quality impacts on crop yields and makes crops vulnerable to import restrictions from countries with strict quality standards (DWS, 2017b). High levels of nutrients and algal blooms in the Breede and Berg River systems is a critical risk threatening international markets in the Western Cape (Cullis *et. al.*, 2018). The severity of algal blooms causes contamination in the rivers, resulting in livestock and wild animal deaths in game reserves and national park (van Ginkel, 2011); a big threat to the tourism, recreation and property

value sectors. Eutrophication has a number of side effects with undesirable ecological and economic consequences that include increased autotroph biomass, species compositional shifts, reductions in biodiversity, potential production of algal toxins, oxygen depletion, taste and odour (Graig *et.al*. 2014).

The 2002 survey has indicated that Department of Water and Sanitation (DWS) (then Department of Water and Forestry (DWAF) regional offices lacked the capability to implement desirable eutrophication management programmes for water resources under their jurisdiction, as desired by published policy and prescribed by the National Environment Management Act (NEMA) and the National Water Act (NWA) legislations (DWAF, 2003); and the situation remains the same up to date. The issue of eutrophication had not received adequate attention previously, which could have been one of the reasons the situation exacerbated even more. An urgent need to rectify this situation was therefore identified, that led the DWS to revise, update and consolidate its policies and strategies and came up with the Integrated Water Quality Management (IWQM) Policies and Strategies for South Africa in 2016 and 2017 respectively. The IWQM Strategy emphasised eutrophication as an issue of priority amongst others such as salinization, Acid-Mine Drainage, urban pollution and sedimentation. It further sets out the prioritized strategic objectives and actions that need to take place to achieve the vision and mission for water quality management in SA. The strategic action relevant to the study is the development of the strategic action plans to reduce point and non-point (diffuse) sources of water pollution (DWS, 2017b), resulting in nutrient rich water streams/lakes with high algal biomass.

In 2019, the Directorate; Sources Directed Control within the Chief Directorate: Water Ecosystem of the DWS reinstated a project (as was initially started in 2002 and was never completed) with the objective to develop the National Eutrophication Strategy. The project is aimed at the development of the National Eutrophication Strategy and putting the Strategy into Practice (the actual implementation of the strategy). The development of the National Eutrophication Strategy is given effect to the strategic objectives and actions identified in the existing IWQM Policy (2016) and IWQM strategy (2017). Eutrophication management is one of the more pressing water quality challenges that form an IWQM Policy statement. The need to manage the eutrophication problem as an issue of priority was amongst others identified by the IWQM Strategy. Chapter 3 of the NWA entails the protection of the water resources, as aligned with the other strategic policies such as the Sustainable Development Goals (SDG6), National Water Resources Strategy Third Edition (NWRS-3), the National Water and Sanitation Master Plan (NW&SMP) and the Resource Directed Measures (RDM).

The Department's approach to the protection of the water resources is two-pronged: the RDM and Source Directed Controls (SDC). The SDC sets controls to prevent water quality pollution and degradation. RDM set the goals for resource protection and are informed by the Water Resource Classification system, which allows for different levels of protection for different water resources. The RDM also make provision for the water resource classification and the determination of the Reserve (the water quantity and quality needed to maintain aquatic ecosystems as well as the water required to meet basic human needs) and Resource Quality Objectives (RQOs). In the absence of the RQOs, certain catchments have implemented the agreed Resource Water Quality Objectives (RWQOs).

Lessons learned from the international literature survey and the national project experiences are as follows:

1. **<u>Developed versus developing countries challenges</u>**

Globally, the most prevalent water quality challenge is nutrient loading, which, depending on the region, is often associated with pathogen loading (UN, 2018). In developed countries such as New Zealand, Australia and United States of America (U.S.A), their sources of pollution (mostly phosphorus than nitrates) causing eutrophication ranges from volcanic eruptions / stratification to nutrients loads (due to industrialization) as the controlling factor (White, 1983; Walmsey, 2003; Davies and Threlfall, 2006; and U.S EPA, 2008). In order to manage eutrophication, New Zealand developed a trophic status assessment using chlorophyll as a method to estimate phytoplankton biomass. Australian research focuses on nutrient transport and sediment-nutrient release models development; whereas the U.S.A developed the Strategy to address water and climate issues, giving special attention to water infrastructure issues (U.S EPA, 2008).

The economic challenges of the developing countries in low- and lower-middle income status are primarily because of higher population, economic growth and lack of wastewater management systems, leading to the country's exposure to water pollutants (Gao and Zhang, 2010; and UN, 2018). These are similar kind of challenges SA has been experiencing for the past five decades (DWA, 1988).

2. South African's water policy

South Africa's environmental and water policies reflects a strong message that aquatic resources and water quality are priority issues of environmental concerns as they provide ecosystem services and water availability. Water availability has to consider the present and future generation needs, i.e. to cater for the country's transitioning economy in light of the National Development Plan & post Covid-19 economic pathway. Therefore, appropriate strategies should be developed and implemented to prevent degradation, economic costs such as water treatment costs and agricultural loss due to crop export limitations. The survey of the South African regional situation demonstrates that eutrophication can be regarded as a national water quality problem in that it has severely degraded certain aquatic systems, and also affects the fitness for use of many water resources throughout the country. With increasing development, it has the potential in the future to affect all water resources.

Eutrophication is one of the most widespread water quality problems in South Africa and in many countries therefore there is a need to protect and recover aquatic resources from this problem. Nutrient management in water resources is the key to addressing and managing eutrophication (Harding, 2015a).

The low rainfall, made worse by climatic variation (both natural and human induced) makes the South African economy vulnerable to water shortages (Shippey *et al.*, 2004). Water bodies in South African manifest high nutrient enrichment and eutrophication related problems. It is a great concern that South Africa's WWTWs are failing to produce effluent that is low in nutrient concentration (DWA, 1988). Eutrophication also lowers property values and reduces the potential for recreational uses. Cyanobacteria blooms can also directly affect the health of people, livestock (Matthews and Bernard, 2015) and cause changes of ecological community structures and loss of biodiversity, resulting in fish and invertebrate mortalities are constantly experienced in the hyper-eutrophic dams *e.g.* the Hartbeespoort and Rietvlei dams.

As indicated by the 2002 survey then, the DWS (then DWAF) regional offices status on lack of capacity to implement desirable eutrophication management programmes remains the same (DWAF, 2003). The issue of eutrophication has not received adequate attention from DWAF policy makers and planners then, which could have been one of the reasons the situation exacerbated even more. An urgent need to rectify this situation was therefore identified, that led the DWS to revise, update and consolidate its policies and strategies and came up with the Integrated Water Quality Management (IWQM) Policies and Strategies for South Africa in 2016 and 2017 respectively.

The IWQM Strategy amongst others emphasised eutrophication as an issue of priority and commits personnel within the Department to develop and implement a workable strategy. It further sets out the prioritized strategic objectives and actions that need to take place to achieve the vision and mission for water quality management in SA. The strategic action relevant to the study is the development of the strategic action plans to reduce non-point sources of water pollution (DWS, 2017b), resulting in nutrient rich water streams/lakes with high algal biomass.

The main objectives on the National Eutrophication Strategy include the following:

1. To promote the allocation of resources (human, financial and technical) to deal with the problem;
2. To operationalize the IWQM Strategy i.e. provide the country with appropriate direction on how eutrophication should be controlled and managed;
3. To monitor and report on the national status on coordinated efforts/intervention towards effective management of Eutrophication problem;
4. To promote the development of the national Eutrophication centred capacity through activities such as training, research and awareness campaigns; and
5. To promote localisation of interventions that entails amongst others: implementation of catchment assessment, monitoring stakeholder engagement and implementation of catchment actions. It should also spell out the role of DWS, Water Management Areas (WMAs), Catchment Management Agencies (CMAs), Water User Association (irrigation boards), water boards, and local authorities, water users (*i.e.* agricultural, mining and industrial sectors).

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ABBREVIATIONS AND ACRONYMS

Acronym	Meaning
CBA	Cost Benefit Analysis
Chlorophyll-a	Chl-a
CMA	Catchment Management Agency
DWA	Department of Water Affairs
DWS	Department of Water and Sanitation
GCM	General Circulation Models
HDRP	Hartbeesport Dam Integrated Biological Remediation Programme
IWQM	Integrated Water Quality Management
LTAS	Long Term Adaptation Scenarios
N	Nitrogen
NES	National Eutrophication Strategy
NWA	National Water Act, 1998 (Act 36 of 1998)
NWRS-2	National Water Resource Strategy Second Edition (2013)
NWRS-3	National Water Resource Strategy Third Edition (2021)
NW&SMP	National Water and Sanitation Master Plan
P	Phosphorus
PMO	Phosphorus Management Objective
PPPFA	Preferential Procurement Policy Framework Act, No.5 of 2000
RCP	Representative Concentration Pathway
RDM	Resource Directed Measures
RQOs	Resource Quality Objectives
SA	South Africa

SDC	Sources Directed Control
SDG	Sustainable Development Goals
TMDLs	The Total Maximum Daily Loads
TSP	Trophic Status Project
WDCS	Waste Discharge Charge System
WQM	Water Quality Management
WWTW	Wastewater Treatment Works

GLOSSARY

Anthropogenic. Negative impacts of human activities. **Aquatic ecosystem.** Complex of biotic and abiotic components of natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and non-living components of the aquatic ecosystem interact and influence the properties and status of each component.

Biomass. The total quantity or weight of organism in a given area of volume.

Catchment or drainage basin. In relation to a watercourse(s) or part of a watercourse, means the area from which any rainfall will drain into watercourse(s) or part of a watercourse, through surface flow to a common point(s). The land area from which a river or reservoir is fed, also known as a drainage basin or watershed.

Chlorophyll a. Chlorophyll used in oxygenic photosynthesis, which contributes to the green colour of most plants such as algae.

Cyanobacteria. Also called blue-green algae, are photosynthetic microbes that occur in most inland waters and can have major effects on water quality and aquatic ecosystem. They may produce taste, odour, toxins and noxious bloom.

Dissolved oxygen (DO). The amount of oxygen dissolved in water. This term also refers to a measure of the amount of oxygen available for biochemical activity in a water body, an indicator of the quality of that water.

Ecosystem. An interactive system that includes the organisms of a natural community association together with their abiotic physical, chemical, and geochemical environment.

Effluent. Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.

Epilimnion, The water above the thermocline

Eutrophic. A state of an aquatic ecosystem rich in nutrients, very productive in terms of aquatic animal and plant life and exhibiting increasing signs of water quality problems.

Eutrophication. Process of nutrient enrichment and the associated excessive plant growth such as algae and macrophytes in water bodies which can be seen as either a natural aging process in lakes or accelerated by human impacts.

Freshwater. Water that contains minimal quantities of dissolved salts (not sea water or brackish water). It comes from precipitation of atmospheric water vapour or melting snow, reaching inland lakes, rivers and groundwater bodies.

Hydraulic retention time. The ratio between the reactor volume and the feed flow rate. It represents the average time the cells and substrates stay inside the reactor.

Hypertrophic. A state of an aquatic ecosystem associated with very high nutrient concentrations where plan growth is determined by physical factors. Water quality problems are serious and almost continuous.

Hypolimnion. The water below the thermocline. This may become anaerobic under nutrient-rich conditions

Macrophytes. Plants that grow in or near water and is either emerged, submerged, of floating.

Mean Annual Runoff (MAR). The average amount of water that flows in a river per year (annum), expressed as cubic meters per annum.

Mesotrophic. A state of an aquatic ecosystem with immediate levels of nutrients, fairly productive in terms of aquatic animal and plant life and showing emerging signs of water quality problems.

Monitoring. Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.

Nitrogen. Is a colourless and odourless element found in the soil, gas and water.

Nonpoint source. Pollution that originates from diffuse sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

Nutrient limitation. Phosphorus is usually considered the "**limiting nutrient**" in aquatic ecosystem. The available quantity of this nutrient controls the pace at which algae and aquatic plants are produced.

Nutrient loading. Excessive amounts of nutrients, leading to pollution.

Oligotrophic. A state of an aquatic ecosystem low in nutrients and not productive in terms of aquatic animal and plant life.

Phosphorus. It is a chemical element which is highly reactive and never found as a free element.

Phytoplankton. Plan plankton found floating in a water body.

Plankton. Organisms drifting in freshwater bodies.

Primary production. Production of chemical energy in organic compounds by living organisms.

Point source. Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.

Pollution. Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, chemical and biological.

Runoff. The water that is running across land surfaces, replenishing groundwater and surface water as it percolates into an aquifer or moves into a river, stream or watershed.

Secchi disk depth. Is a 20cm disk with alternating black and white quadrants. It is lowered into the water of a lake or dam until it can no longer be seen by an observer, the depth of disappearance is called the Secchi depth.

Stratification. Occurs as a results of a density differential between two water layers which can arise due to as a result of the differences in salinity, temperature or a combination of both.

TMDL (OR Pollutant Load Allocation) is the maximum amount of a pollutant that a waterbody can assimilate before undesirable physical, chemical and/or biological thresholds are exceeded and the 'fitness for use' of the water resource becomes impaired.

Thermocline. An abrupt temperature gradient in water bodies such as lakes, marked by two layers of water bodies at different temperatures.

Tropic status. The degree of Oligo nutrient enrichment and of the associated eutrophication problems of an aquatic.

Turnover. The rate in which employees leave a workforce and are being replaced.

Wastewater. Any water used from domestic, industrial, commercial or agricultural activities, surface runoff or storm water, which may contain physical, chemical and biological pollutants.

Wastewater treatment. Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.

Water quality. The biological, chemical, and physical conditions of a waterbody. It is a measure of a water body's ability to support beneficial uses.

Water quality standard. Law or regulation that consists of the beneficial designated use or uses of a water body, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an anti-degradation statement.

Zooplankton. Small animals and the immature stages of larger organisms drifting in freshwater bodies.

CHAPTER 1 - BACKGROUND AND INTRODUCTION

1.1. INTRODUCTION

One of the mandates of the Department of Water and Sanitation (DWS), as the custodian of the country's water resources is to protect water resources for current use and future generations. This can be achieved by managing water quality of the resource in an integrated way. Integrated Water Quality Management Strategy (2017) recognizes eutrophication as one of the priority water quality issues in South Africa (SA).

Eutrophication leads to a progressive deterioration of water quality and other undesirable changes that interfere with water use, by reducing its suitability for use (DWA, 1986). It has a number of side effects with undesirable aesthetic, recreational, health, ecological and economic consequences that include taste and odour, production of algal toxins increased autotroph biomass, species compositional shifts, reductions in biodiversity, potential oxygen depletion, increased water treatment costs and loss of property value (Griffin, 2017). It constitutes a major threat to the provision of raw potable and irrigation water in South Africa (SA), being largely dependent on impounded water for water supply (Harding, 2008). Poor water quality impacts on crop yields and makes crops vulnerable to import restrictions from countries with strict quality standards (DWS, 2017b). High levels of nutrients and algal blooms in the Breede and Berg River systems is a critical risk threatening international markets in the Western Cape (Cullis *et. al.*, 2018). The severity of algal blooms causes contamination in the rivers, resulting in livestock and wild animal deaths in the Kruger National Park, SA (van Ginkel, 2011); a big threat to the tourism, recreation and property value sectors. Eutrophication has a number of side effects with undesirable ecological and economic consequences that include increased autotroph biomass, species compositional shifts, reductions in biodiversity, potential production of algal toxins, oxygen depletion, taste and odour (Griffin, 2017).

The word 'eutrophic' comes from the Greek word '*eutrophos'* meaning well-fed. For the purpose of this report, eutrophication is defined as the enrichment of water with plant nutrients which results in an array of symptomatic changes, namely increased production of algae and aquatic macrophytes, deterioration of water quality and other undesirable changes that interfere with water use (OECD, 1982 and Rossouw *et al*. 2008). Whereas, van Ginkel (2011) described eutrophication as a process of nutrient enrichment and the associated excessive plant growth such as algae and macrophytes in water bodies, which can be seen as either a natural aging process in the aquatic ecosystems or accelerated by human impacts. Thornton *et. al.* (2013) recognized Eutrophication as a wicked problem which requires site-specific approaches, based on specific knowledge of individual water bodies, as well as an ongoing commitment to lake and reservoir management to respond to new manifestations of the problems of nutrient enrichment as they continue to be revealed over time.

Eutrophication is a water resource issue in most industrialized countries. Factors influencing eutrophication are high nutrient concentrations, prolonged periods of water stagnation, suitable temperature, oxygen concentration and proper light regime. Comprehensive eutrophication research impact assessment has been performed by the Water Research Commission (Frost and Sullivan, 2010).

The two main eutrophication sources are point and diffuse (also known as non-point) sources of pollution. The point sources are associated with pipeline discharge of effluent from facilities such as Waste Water Treatment Works (WWTWs) and industrial discharges; whereas diffuse sources of pollution emanate mainly from the atmospheric deposition process (nutrients leaching from certain rocks and soils), settlements (urban, peri-urban and informal) and agricultural run-off (DWA, 1986).

1.2. THE PURPOSE OF THE REPORT

The purpose of this report is to identify current as well as emerging eutrophication issues, causes, impacts and challenges. The identification of the causes and challenges were conducted through the review of existing literature, reports, models, maps, photographs and other relevant information relevant to the development of the National Eutrophication Strategy. Identified data and information gaps, together with measures to address those gaps will be explained.

This report includes the following:

- The impacts of climate change,
- International Water Quality status in relation to SA,
- Eutrophication management policy and legislative framework,
- Eutrophication challenges in SA,
- Measures in place to manage eutrophication,
- Gap analysis, and
- Proposed interventions.

1.3. THE HISTORY OF EUTROPHICATION MANAGEMENT IN SOUTH AFRICA

Eutrophication was recognized as a threat to South African (SA) surface waters almost seven (7) decades ago and the first impacts thereof became apparent in the 1950s and reaching problematic levels in the 1960s (Walmsley and Butty, 1980; Zohary *et al.,* 1988; van Ginkel, 2011).

In 1962, the then Department of Water Affairs (DWA) developed a Regional Standard for Industrial Effluents and the Wastewater General and Special Standards of 2 milligrams per litre of Phosphate (2mg/l P). The 2mg/l P was only meant to be applicable in 73 specific catchments, however its enforcement is yet to be confirmed as it was said to be stricter then (Harding, 2017).

In early 1970s, eutrophication was considered a serious water problem and a need to address the dangers that eutrophication posed to water supply was sought. The then DWA and the Bureau of Standards initiated the study on the causes, consequences and control of eutrophication. The Water Research Commission (WRC) in collaboration with the National Institute of Water Research (NIWR) led a study on 21 South African dams to determine the relationships between trophic status and nutrient characteristics (Walmsley and Butty, 1980). Late 1970s, DWA foresee economic impacts of eutrophication if the current issues were left unattended (Harding, 2017).

In 1980, the then DWA promulgated a special phosphorus standard (1mg/l Ortho-phosphorus) on effluent intended for use in selected sensitive catchments (GNR 1567 in Government Gazette 7159 of August 1980 Special Standard for Phosphorus, as amended from the 1956 Standards). The implementation of the 1mg/l P-Standard was expected to reduce nutrient load from the Wastewater Treatment Works (WWTW), but was criticized for being general rather than on a case-specific basis depending on nutrient load. A five (5-) year extension of the 1mg/1 P-Standard implementation was granted to allow local authorities more time to upgrade WWTW to comply with the standard, until commencement in 1985 (Taylor et. al., 1984; DWA, 1988; and Harding, 2017).

In 1985, the Department of Water Affairs developed and implemented a Trophic Status Project (TSP) aimed to monitor the effectiveness of the 1 mg/l P effluent discharge standard on the water quality of the specified impoundments in the selected sensitive catchments, which are the Vaal River catchment up to the Barrage, the Crocodile River catchment up to the confluence of the Crocodile and Pienaars rivers. The emphasis of the Trophic Status Project (TSP) shifted from ascertaining the effectiveness of the 1mg/l P-Standard to determining the trophic status of impoundments in 1990. The shift meant that the focus of eutrophication monitoring changed from effluent discharge to in-lake concentration monitoring. In 1991, DWA introduced a Precautionary Approach of managing eutrophication that emphasized avoiding and reducing pollution threats (Harding, 2017).

In 2001, DWA undertook a project to assess the Trophic Status Project in relation with the P-Standard. The results indicated that the 1 mg/l P-Standard showed reductions in phosphorus in some of the dams in the priority catchments, with no significant changes to the trophic status of the impoundments. One of the recommendations from the study was the need to develop an extensive, National Eutrophication Monitoring Programme (NEMP) for the rest of the country (Van Ginkel *et al.,* 2000 and Walmsley, 2003), which is currently in place.

CHAPTER 2 – LITERATURE SURVEY

2.1. WATER POLLUTION AND EUTROPHICATION

South Africa faces a wide range of water quality challenges impacting on both surface water and groundwater, originating from both point source discharges such as mining, industrial processes and municipal Wastewater Treatment Works (WWTW), and from diffuse sources due to run-off from land. The pollution challenges manifest at various scales, differ between catchments, and have different severity of impacts such as eutrophication, salinization, Acid-Mine Drainage, urban pollution and sedimentation. Add to that the increasing demands for limited water supplies, deteriorating raw water quality and changes in temperature and rainfall due to climate change, if not addressed urgently, will significantly limit our socio-economic growth.

Eutrophication is defined as the enrichment of water with plant nutrients which results in an array of symptomatic changes, namely increased production of algae and aquatic macrophytes, deterioration of water quality and other undesirable changes that interfere with water use (OECD, 1982 and Rossouw *et al*. 2008). The two main eutrophication sources are point and diffuse (also known as non-point) sources of pollution. The point sources are associated with pipeline discharge of effluent from facilities such as Waste Water Treatment Works (WWTWs) and industrial discharges; whereas diffuse sources of pollution emanate mainly from the atmospheric deposition process (nutrients leaching from certain rocks and soils), settlements (urban, peri-urban and informal) and agricultural run-off (DWA, 1986).

The trophic status is used as the description of the water body to indicate the stage at which eutrophication is at any given time; and can be classified by the level of nutrient enrichment as oligotrophic, mesotrophic, eutrophic and hypertrophic, ranging from minimum impact on water quality (oligotrophic) to maximum impact water quality (hypertrophic). The following terms are used to describe each stage of the process (DWAF, 2002):

- Oligotrophic - a state of an aquatic ecosystem low in nutrients and not productive in terms of aquatic animal and plant life.
- Mesotrophic - a state of an aquatic ecosystem with immediate levels of nutrients, fairly productive in terms of aquatic animal and plant life and showing emerging signs of water quality problems.
- Eutrophic - a state of an aquatic ecosystem rich in nutrients, very productive in terms of aquatic animal and plant life and exhibiting increasing signs of water quality problems.
- Hypertrophic - a state of an aquatic ecosystem associated with very high nutrient concentrations where plan growth is determined by physical factors. Water quality problems are serious and almost continuous.

2.2. WATER QUALITY STATUS BENCHMARK IN OTHER COUNTRIES

Since the early 1990s, water pollution has worsened in almost all rivers in Africa, Asia Canada and the United States of America (U.S.A). The deterioration of water quality is expected to further escalate over the next decades and this will increase threats to human health (U.S EPA, 1998).

Globally, the most prevalent water quality challenge is nutrient loading, which, depending on the region, is often associated with pathogen loading. Hundreds of chemicals are also impacting on water quality. The greatest increases in exposure to pollutants are expected to occur in low- and lower-middle income countries, primarily because of higher population and economic growth and the lack or inadequate wastewater management systems (Gao and Zhang (2010; United Nations (UN), 2018). U.S.A played a major role in developing the Strategy to address water and climate issues, giving special attention to water infrastructure issues (U.S EPA, 1998).

White (1983) indicated that the state of eutrophication differs from country to country, for example, in New Zealand and the other central volcanic plateau of the North Island, phosphorus is the principal factor causing eutrophication compared to nitrates; whereas in Australian inland waters and estuaries, the eutrophication process is influenced by the stratification and light as the main factors to algal blooms in impoundments than nutrients load (Davies and Threlfall 2006). Although nutrients loads are known to have a controlling factor on algal blooms biomass. Australian research focus is now on nutrient transport and sediment-nutrient release models development.

Eutrophication has become a major problem detrimentally related to nutrient accumulation, mostly from the sewage effluent, affecting ecosystem functioning and different industries such as fishing industry in large lakes around the USA, Canada, Italy and Africa (Edmondson, 1974, Sitoki *et. al.* 2010).

Due to increasing amounts of treated sewage over the years and the increase in water temperature, the USA's Lake Washington and the Italian Lake Maggiore confirmed to have eutrophication challenges due to increased phosphorus concentrations in water and sediment, together with the presence of blue-green algae (Edmondson *et. al*. 1955; Edmondson, 1974 and Morabito *et. al*. 2013). Lessons learned from the USA and Canadian perspectives are the adoption of an "Adaptive Ecosystem Management" as a way to go in solving eutrophication in Lake Tahoe (Elliott-Fick *et. al*. 1997); and the "Adaptive Governance Approach" in lake Erie (Saviti and Gail, 2016). The Adaptive Ecosystem Management relates to taking into account the value of citizen involvement in environmental issues; whereas "Adaptive Governance Approach" considers the public participation framework including diversity amongst people or group of stakeholders with different values and interests (Elliott-Fick *et. al*. 1997 and Saviti and Gail, 2016).

Increased temperature and plant nutrients concentration led to the eutrophication processes with ecosystem conditions of deteriorating water quality and a threat to sustainable utilization of lake resources such as fisheries in Lake Victoria (East Africa) (Gikuma-Njuru *et. al*. 2005 and Sitoki *et. al.* 2010).

In Egypt, Africa, Abdel-Azeem et al. (2006) conducted a study in Lake Manzala, which was found to be in great danger of suffering pollution from drainage of industrial and urban sewage that affected the physio-chemical and biological parameters in the lake. The results from the study indicated that nutrients from major drains have created eutrophication conditions in those parts of the lakes that are closest to the drains outlets; and sectors (northern sector and parts of western sector) that were not affected by wastes and nutrients loading provided a reservoir for "natural" fish and other aquatic species (Abdel-Azeem *et al*. 2006).

Thornton *et al*. (2013) reported that studies conducted in Lake Chivero, in Zimbabwe (Africa), came up with a series of interventions leading to the water quality improvement, which was short-lived as the growth of urban density developments a decade later lead to the nutrient re-enrichment of the lake as a result of non-point sources of pollution. The process of cultural eutrophication is no stranger to SA (Rossouw *et al*. 2008), the same situation happened in Hartbeespoort dam in SA, where urban growth within the catchment led to nutrient enrichment of the reservoir (Thornton *et al*. 2013).

2.3. CLIMATE CHANGE IMPACTS AND EUTROPHICATION

2.3.1. Background

Climate change is a global reality and the increasing temperatures severely affect freshwater systems and human populations which rely upon them. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014) notes that 93% of the impacts associated with climate change will be felt in the water sector. One form of water pollution is water eutrophication, which occurs when high concentrations of nutrients, such as nitrogen and phosphorus, are present in the water.

The Fifth Global Environment Outlook (GEO-5) reports that more than 40% of water bodies all around the world suffer from different levels of eutrophication (UNEP, 2012). The reason for this phenomenon is an important issue of great concern with its potential consequences, threatening the reliable supply of drinking water. Climate change can, directly and indirectly, affect eutrophication, as a result of interactions between meteorological factors and nutrient availability (Whitehead et al., 2009). The existing literature shows that sensitive factors to climate change such as water temperature, precipitation, wind, and solar radiation can affect trophic conditions in water bodies (van Ginkel and Silberbauer, 2007).

2.3.2. Temperature

Temperature is an important environmental factor that influences chemical and physical properties in water ecosystems such as pH, salinity, solubility, and diffusion rates, and can consequently affect water eutrophication potential (Mooij, 2007). Air temperature and temperature in water bodies are in close equilibrium. Hence one of the immediate reactions to climate change is expected to be alterations in water resources temperatures (Ihnken, 2010).

Global average surface temperature is expected to rise over the next 100 years from 2.6 °C to 4.8 °C. Therefore, the measure of uncertainty and time series of projections show that by the end of the 21st century, the global average surface temperature will certainly increase in the future (IPCC, 2014).

When water temperature and nutrient concentrations increase, algae growth is stimulated, leading to water eutrophication and algal blooms (van Ginkel and Silberbauer, 2007). As concentrations of phosphorous and nitrogen increase in dams, rivers, estuaries and lakes the cyanobacteria become increasingly dominant. As a result, dissolved oxygen concentrations can fluctuate widely and algal productivity may reach problematic levels. A significant influence on oxygen concentrations is temperature; higher temperatures reduce dissolved oxygen in water bodies. The conditions of most in-stream dams in SA have deteriorated over the years due to the inclement weather which resulted in more inflow in the dam exacerbated by human intervention.

2.3.3. Precipitation (The Influence of Climate Change in Water Availability)

Besides the temperature effects, the change in hydrological regimes are also consequences of climate change. As the temperature is predicted to rise, the rate of precipitation is likely to drop and evaporation to increase (IPCC, 2014). Climate model mean projections for 2081-2100 compared to 1986-2005 indicate high variability in annual mean precipitation globally with projections indicating an increase in some areas and a decrease in some areas.

The average annual rainfall in SA is about 497mm, which is well below the global average of 860mm. Approximately 65% of the country is arid and semi-arid, affecting the reliability and variability of river flow and groundwater recharge, Water availability is poorly distributed in SA and culminates into extreme events, periodically afflicted by severe and prolonged droughts and regularly subjected to floods (DWA, 1986).

In areas with projected higher precipitation, it is possible that intense extreme precipitation events resulting in floods will occur and cause more erosion and re-suspension of sediments, ultimately resulting in higher concentrations of sediments and nutrients in receiving water bodies (Whitehead et al., 2009). Less precipitation culminates into drought and can also increase the risk of eutrophication by lowering minimum flows. Therefore, due to climate change conditions and anthropogenic activities altering water flows, water bodies are exposed to greater nutrient loads, which can ultimately lead to water quality deterioration. In this case, less water volume will be available for dilution of pollutants. As a result, increased concentration of nutrients can deplete dissolved oxygen concentration (DO) and increasing biochemical oxygen demand (BOD) (Whitehead *et al.*, 2009). A combination of drought and high level of nutrient enrichment can lead to contamination of water bodies by deadly cyanobacteria toxins.

2.3.4. *Wind*

The wind will also be affected by climate change, and will have direct and indirect impacts on water resources. The direct effects of wind refer to blowing of algae from the water surface to the lakeshores or river banks and influencing these regions by accumulating algal blooms scums and toxins concentration and changing environmental conditions. The indirect effect is the disturbance caused by the wind, which can circulate the water and mix different layers of the water column. This circulation enhances the mixture of nutrients and accelerates the release of nutrients from sediments (Matthews, 2019).

The wind will have direct and indirect impacts on water trophic conditions, but it does not act as a single decisive operator, and mostly influences eutrophication along with other meteorological factors.

2.3.5. Solar Radiation

Global warming and solar radiation have mutual connections (Frey et al., 2011). A recent study observed and projected from 1960 to 2100 changes in annual mean UV-B radiation at the Earth's surface for different latitude bands (IPCC, 2014). Projected UV-B radiation compared with 1980 levels, showed increasing trends at 60° to 90° southern latitude (more than 20% increase), and decreasing trends at 60° to 90° northern latitude (around 10% decrease).

As an important source of energy, solar radiation plays a crucial role in photosynthesis in different ecosystems and is an essential factor for the growth of phytoplankton and other aquatic species. Sufficient sunlight increases water temperature and the presence of nutrients altogether provide suitable conditions for the growth of algae and phytoplankton, finally resulting in water eutrophication. Algae distribution is also dependent on the intensity of solar radiation received at different depths. However, increased sunlight will not necessarily cause more algae growth. There is a maximum growth rate for algae, in which beyond this threshold, the growth rate will decrease (Craig et al., 2014).

The impacts of climate change are exacerbated by rapid population growth, rapid urbanization and chaotic economic development, particularly where water demands already exceed limited supplies.

2.3.6. South Africa's Current and Future Climate

Dams, reservoirs and other water bodies respond directly to climatic changes and the variability in these responses are likely to affect water resources in terms of water availability, water quality and aquatic ecosystems.

In 2013, the Water Research Commission commissioned a study to investigate the effects of the projected climate change on eutrophication and related water quality as well as secondary impacts on the aquatic ecosystem. Some of the key findings were that human activities are the main causes of eutrophication, as increased concentrations of phosphorous and nitrogen are discharged into water bodies. The study recommended that collaboration and alignment of activities among Government departments, private sector and communities should be encouraged. Other important considerations for improved water management given climatic effects and other stressors include compliance monitoring and enforcement, awareness raising as well as capacity building.

South Africa's climatic conditions, coupled with the discharge of treated and untreated sewage effluent and excessive nutrient loads in return flows from agriculture, as well as modification of river flow regimes and changing land use or land cover patterns, have resulted in large-scale changes to aquatic ecosystems that have resulted in the eutrophication of rivers and water storage reservoirs (Van Ginkel, 2011).

Large areas of South Africa are arid to semi-arid and experience erratic and unpredictable extremes of drought and floods. Lakes and reservoirs that receive point source nutrient inputs also experience high rates of evaporation as well as long periods when river inflows and outflows decline. In combination, these circumstances lead to rapid rates of eutrophication where large proportions of the inflowing nutrient loads are retained within the water body and its sediments, favouring the development of cyanobacteria blooms (NIWR, 1985). South Africa is located in a negative runoff zone, where annual evaporation exceeds rainfall by a factor of between 1.2 and 4 and, on average; approximately 8% of South Africa's annual rainfall becomes available as surface runoff (Ashton *et al.*, 2008).

CHAPTER 3 - POLICY AND LEGISLATIVE FRAMEWORK ON EUTROPHICATION MANAGEMENT

3.1. THE SUSTAINABLE DEVELOPMENT GOALS

The 17 United Nations (UN)'s Sustainable Development Goals (SDGs), which replaced the Millennium Development Goals are a universal set of goals, with targets and indicators that UN member states will be expected to use to frame and guide their agendas and political policies over the next 15 years.

The SDGs adopted in December 2015, are aimed at ending poverty, protecting the planet, and ensuring prosperity for all as part of a new sustainable development agenda. The SDGs were endorsed by all Heads of State, including SA, and it serves as a reporting channel to measure progress towards sustainable development and help to ensure the accountability of all stakeholders for achieving the SDGs by 2030 – which marks 15 years after its adoption in 2015 (SDSN, 2015).

The SDG 6 goal focuses on clean water and sanitation, and it is driven through eight targets and eleven indicators that will be used to propel different components and monitor progress. One (1) **SDG 6** target that is relevant to the development of the Eutrophication Strategy is **target 6.3** which addresses the improvement of wastewater treatment and water quality. There are three targets under SDG 6 that are particularly relevant to water quality, of which the development of the Eutrophication Strategy aims to give effect to:

- By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.
- By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally; and
- By 2030, implement integrated water resources management at all levels, including through trans-boundary cooperation as appropriate.

The SDG's further emphasized the need to implement the 2020 and 2030 targets in order to improve the healthy functioning of the water resource from both a security and development point of view as required. In support of the SDGs, Eutrophication is one of the five water quality issues identified as High Impacts amongst Salinization, Sedimentation, Acidification and Urban Pollution (DWS, 2017b). That constitutes a need to prioritised water quality management issues and pollution prevention and control, hence the development of the National Eutrophication Strategy.

The achievement of the SDGs may be constrained by inadequate institutional governance and infrastructure, leading to lack of cooperation in flood and droughts management, lack of adequate water supplies and sanitation provision.

3.2. SOUTH AFRICAN CONSTITUTION

The foundation for water quality protection in South Africa is provided by the **Constitution of the Republic of South Africa, 1996**. Section 24(a) of the Constitution provides fundamental and dual solidarity rights to an environment that is not harmful to one's (i) health or (ii) well-being. To place water within the context of this right one has to examine the definition of 'environment' that is contained in the National Environmental Management Act (NEMA).

3.2.1. The National Environmental Management Act (NEMA -Act 107 of 1998)

In NEMA, the environment is defined as "the surroundings within which humans exist and are made up of:

- The land, water and atmosphere of the Earth;
- Microorganisms, plant and animal life;
- Any part or combination of the above and the interrelationships among and between them; and
- The physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being.

The definition of the environment also includes the remit of aquatic ecosystems and therefore the NEMA principles apply to all issues affecting water quality in the water resources and pollution thereof.

NEMA considers pollution as any alteration of the environment due to substances, radioactive, noise, odour, dust or heat. NEMA advocates that the principle of sustainable development is paramount and that all development must be socially, environmental and economically sustainable. Sustainable development supports the hierarchy of decision-making.

NEMA also makes provision for all spheres of government (national, provincial and local) to participate cooperatively in the governance of the environment.

3.2.2. National Water Act (NWA – Act 36 of 1998) and the Water Services Act (WSA – Act 107 of 1997)

The National Water Act (Act 36 of 1998) (NWA) together with the Water Service Act (Act 107 of 1997) (WSA) promotes sustainability and equity as the central guiding principles in the protection, use, development, conservation, management and control of water resources. Chapter 3 of the NWA deals with the protection of water resources and is also focusing on pollution prevention measures; whereas WSA makes provision for the basic water supply and sanitation services. The development of the National Eutrophication Strategy is amongst calls in response to putting pollution prevention measures in place, as a provision for the protection of water resources. It is also highlighted in the spirit of co-operative governance with the emphasis on building capacity at all levels (National, Provincial and local) of Government. The application of the drinking water and wastewater (*e.g.* WWTWs) treatment and discharge processes are controlled and managed through the application of both the NWA and WSA concurrently. Several features to the NWA that merit the inclusion of eutrophication considerations include:

i. **<u>The National Water Resource Strategy</u>**

The National Water Resources Strategy (NWRS) is currently the legal instrument for implementing or operationalizing the NWA (Act 36 of 1998) and it is thus binding on all authorities and institutions implementing the Act. It is the primary mechanism to manage water across all sectors towards achieving national government's development objectives (DWS, 2020). It provides the objective for the protection, use, development, conservation, management and control of the country's water resources sustainably and equitably. It also provides the framework within which water will be managed at regional or catchment level, in defined water management areas.

The NWRS-1 was published in 2004 and the second edition (NWRS-2) was published in 2013, and was the blueprint for water resources management in South Africa. The National Water Resource Strategy 3 (NWRS-3) builds on the NWRS editions 1 and 2, and the revision of the strategy, with the purpose to ensure the protection and management of water resources to enable equitable and sustainable access to water and sanitation services in support of socio-economic growth and development for the well-being of current and future generations in SA. The NWRS-3 is a strategy for all sectors and stakeholders who use South Africa's water resources and it responds to the NWA by outlining strategic objectives and actions which are then carried forward for implementation in the National Water and Sanitation Master Plan (NW&SMP) (DWS, 2020).

ii. National Water and Sanitation Master Plan

The purpose of the National Water and Sanitation Master Plan (NW&SMP) is to rally all the water sector stakeholders in SA to work together in order to ensure that by 2030 and beyond SA will have met SDG 6: Ensure access to water and sanitation service for all is achieved. The Department together with the sector partners, through meaningful engagements, produced three sets of volumes (Volume 1-3) of the NW&SMP. The NW&SMP is the implementation plan for the NWRS-3, which will be reviewed every five years (DWS, 2018). The National Eutrophication Strategy is aligned to the NW&SMP, under the strategic objectives such as" Improving Raw Water Quality" and "Protecting and Restoring Ecological Infrastructure". Key actions are identified under each strategic objective, which will be implemented under relevant institutional arrangements such as Catchment Management Agencies (CMAs).

iii. Catchment Management Strategies

The NWA devolves responsibility to CMAs to progressively develop catchment management strategies for the water resources within their jurisdiction. All catchment management strategies must be in harmony with the national water resource strategy and set principles for allocating water to existing and prospective users and water quality targets together with the operationalization of the catchment implementation plans.

iv. Water Resource Classification System (WRCS)

The Water Resource Classification System (WRCS) is a set of guidelines and procedures for determining the desired characteristics that places water resources (*i.e.* rivers, estuaries, wetlands and aquifers*)* into different categories called Management Classes (MCs). The WRCS prescribes a consultative process with different stakeholders, including civil society to classify water resources to help facilitate a balance between protection and use of the nation's water resources.

v. Water Resource Classification

The water resource classification process outlines those attributes that the DWS and society require of different water resources.

vi. The Resource Quality Objectives (RQOs)

The RQOs are numerical and narrative descriptors of conditions that need to be met in order to achieve the required MCs as provided during the resource classification. In order to ensure that appropriate RQOs are set for each MC, clear goals relating to the quantity and quality of water resources (rivers, wetlands, estuaries and groundwater), required to give effect to the MCs are set. The process stipulates that in determining RQOs a balance is sought between the need to protect, sustain and use water resources (NWA, 1998).

Upon the setting of the RQOs, the implementation of the RDM follows through compliance monitoring. The Reserve is monitored for RQOs compliance in each Resource Unit (either through Ecological Water Requirements (EWR), wetland type, estuary type and aquifer). These include the in-stream flow; the water level; the presence and concentration of substances in the water; characteristics and quality of the water resource and in-stream and riparian habitat; the characteristics and distribution of aquatic biota; and the regulation or prohibition of in-stream or land-based activities which may affect the quality of water or quality of the water resource. In the South African water resources management context, the acceptable level of impact hinges on the concept of RQOs as the balance between resource protection and resource development and utilization (NWA, 1998).

vii. <u>The Reserve</u>

The Reserve refers to the quantity and quality of water that needs to be maintained for the Basic Human Needs and Ecological Needs. The Basic Human Need Reserve provides for the essential needs of individuals served by the water resource such as water for drinking, for food preparation and for personal hygiene. The Ecological Reserve relates to the water required to protect the aquatic ecosystems of the water resource including both the quantity and quality of the water, habitat and biota (NWA, 1998). DWS is required to determine the Reserve for all or part of any significant water resource. Once the Reserve is determined for a water resource it is binding in the same way as the class and the resource quality objectives.

viii. <u>Pollution Prevention Measures</u>

The NWA deals with pollution prevention and in particular the situation where pollution of a water resource occurs or might occur as a result of activities on land. The person who owns controls, occupies or uses the land in question is responsible for taking measures to prevent pollution of water resources. If these measures are not taken, the Catchment Management Agency (CMA) or the proto CMA where the CMA is not yet established, concerned may itself do whatever is necessary to prevent the pollution or to remedy its effects, and to recover all reasonable costs from the persons responsible for the pollution. Eutrophication is a form of pollution, and its management should be incorporated into these pollution control considerations. Some of the pollution prevention measures include measures to:

- Cease, modify or control any act or process causing the pollution;
- Comply with any prescribed waste standard or management practice;

- Contain or prevent the movement of pollutants;
- Eliminate any source of the pollution;
- Remedy the effects of the pollution; and
- Remedy the effects of any disturbance to the bed and banks of a watercourse

ix. <u>Water Uses</u>

Chapter 4 of the NWA which deals with the uses of water (including waste discharges and disposal) and it lays the foundation to regulate water uses. All the regulations, management practices and guidelines developed under this mandate, together with the WSA were considered in the development of pollution control measures.

3.3. INTEGRATED WATER QUALITY MANAGEMENT

3.3.1. The Evolution of Integrated Water Quality Management

South Africa has a long history of policies and programmes for managing water quality, ranging from the Public Health Act, 1919 (Act 36 of 1919*)* of the Union of South Africa, to the NWA that was promulgated in 1998. With the expansion of agriculture, industry and mining over many years, along with population growth and urbanisation and climate change, the impacts on water quality have increased and diversified, and the need for improved Integrated Water Quality Management (IWQM) approaches has become increasingly imperative. A consistent evolution in approach can be seen over the last century (Figure 1).

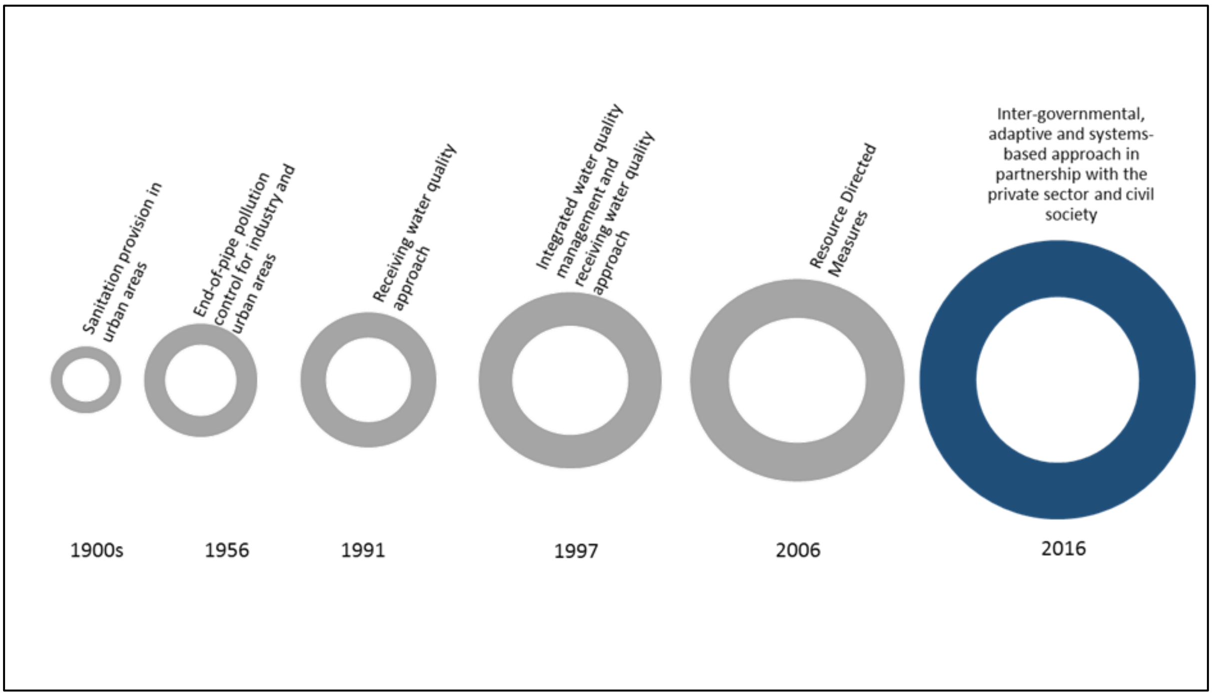

Figure 1: The Evolution of IWQM in South Africa

3.3.2. The Integrated Water Quality Management Policy

According to the National Water Resource Strategy (NWRS–2) and the IWQM Policy (2016), eutrophication has been identified as one of the five high prioritisation in terms of water quality issues of concern amongst salinization, acid mine drainage and acidification, sedimentation and urban runoff pollution. The process of the development of the 2017 IWQM Strategy was parallel to the development of the IWQM Policy where all water quality management policies were integrated to inform a uniform and seamless approach towards water quality management.

A thorough analysis of the eutrophication contained in the IWQM policy further looked at the importance that:
"Eutrophication is of concern because it can have numerous negative impacts, which include ecological impacts (such as the deterioration of water quality and loss of biodiversity), as well as aesthetic, recreational and human health impacts. These negative impacts also have a significant economic impact. The direct impact is the excessive growth of microscopic algae and macrophytes (rooted and free-floating water plants), leading to impacts on recreation and sporting activities; the presence of toxic metabolites in blue-green algae (cyanobacteria); the presence of taste- and odour-causing compounds in treated drinking water; and difficulty in treating the affected water for potable and/or industrial use."

The IWQM Strategy has therefore set out the prioritized strategic actions that need to take place to achieve the vision and mission for water quality management in SA. As a call to operationalize the IWQM Strategy, the DWS developed the IWQM Plan for the Olifants River System in February 2018. Both projects developed strategic actions and plans to reduce non-point sources of water pollution and thus another reason a National Eutrophication Strategy is being developed in order to implement those actions.

3.4. ALIGNMENT WITH OTHER STRATEGIES

The development of a strategy addresses the requirements of the National Water Resource Strategy version 2 (NWRS-2) and the need to improve eutrophication management in SA should be based on the improvement, integration and/or alignment of existing policies and strategies. The development of this strategy is based on the Integrated Water Quality Management (IWQM) Policy developed in 2016. Existing policies, strategies and sector specific strategies and guidelines that inform the strategy includes but not limited to the following:

- DWS, 2020. National Water and Sanitation Master Plan;
- DWS, 2018. Integrated Water Quality Management Plan for the Olifants River

System;

- DWS, 2017. Integrated Water Quality Management Policies and Strategies for South Africa;
- DWS, 2014. Eutrophication: Prevention, Management and Control: Operational Guideline to Develop a Catchment Eutrophication Management Strategy;
- DWA, 2010. Operational Guideline for Best Eutrophication Management Practices.
- DWAF, 2006. Resource Directed Management of Water Quality: Volume 1.2: Policy;
- DWAF, 2006. Resource Directed Management of Water Quality: Volume 2.2: Strategy;
- WRC, 2006. Guidelines for the Utilisation and Disposal of Wastewater Sludge;
- DWAF, 2003. Conceptual Introduction to the Nature and Content of the Water Quality Management and Assessment Components of a Catchment Management Strategy;
- DWAF, 2000. Policy and Strategy for Groundwater Quality Management in SA; DWAF, 1999. A strategic Plan for the Department of Water Affairs and Forestry to Facilitate the Implementation of Catchment Management in South Africa;
- DWAF, 1999. National Strategy for Managing the Water Quality Effects of Settlements; and
- DWAF, 1995. Procedures to Assess Effluent Discharge Impacts.

CHAPTER 4 – EUTROPHICATION CHALLENGES IN SOUTH AFRICA

4.1. CURRENT STATUS OF EUTROPHICATION IN SOUTH AFRICA

Many of the country's impoundments and rivers show high levels of nutrient enrichment and eutrophication related problems which is of great concern as it can result in ecological impacts of the water body, aesthetic, recreational and human impacts (DWA, 2011; and Matthews, 2014). Most of the highly impacted reservoirs are located in the economic heartland of South Africa, which has an extant regional water quality crisis with others showing serious eutrophication potential in other parts of the country (Harding, 2015b).

Between 2002 and 2012, eutrophication was severe and widespread, affecting the overwhelming majority (70) of the 102 water-bodies assessed, and two-thirds of their total surface area. By this measure, South Africa is facing a nutrient enrichment crisis that is driving high levels of cyanobacteria and algal blooms that are significantly deteriorating the quality of much of its surface waters. Given its prevalence, the effects of eutrophication are likely to have caused substantial economic inefficiencies and losses over the last decade (Matthews, 2019). All these have a significant economic impact and largely attributed to the poor state of WWTW that discharges untreated and poorly treated effluent into water-bodies. Non-compliance to the national water resources legislations, policies, best-practices norms and standards is adding to the challenge (Harding, 2008).

The Department of Water and Sanitation in 2008 introduced the Green Drop System that was designed to ensure that wastewater treatment works improve their operations to avoid negatively impacting on water bodies into which they discharge. A total of 449 out of 852 municipal wastewater systems including WWTWs were assessed for the first Green Drop Certification programme and only 5% (32 WWTWs) of the assessed WWTWs achieved the Green Drop Status (scored 90% and above), 39% achieved from 50-89% meaning there is room for improvement in some key performance areas. The remaining 56% of the assessed WWTWs scored below 50% which was of great concern. It was also found that of the 449 works that were assessed, skills shortages had resulted in many not being operated correctly and hence the non-compliant with regard to their effluent water quality (DWA, 2012 and DWA 2013). Besides the risks to human health of sewage water discharged into rivers and dams from poorly managed WWTWs, the poorly treated or contaminated water can pose a risk if the contaminated rivers or dams are used as drinking water for livestock animals and crop irrigation. The Green Drop reporting was stopped in 2014 and the Department's plan in place for this financial year is that stakeholders will do self-assessment and load information into the Integrated Regulation Information System (IRIS).

Water bodies receive both sewage phosphorus and detergent phosphorus discharges and a study was conducted to determine the percentage of detergent phosphorus in the total phosphorus found in domestic sewage (Quayle et. al, 2010). It was found that the detergent phosphorus made up to 32% of the total domestic sewage phosphorus and contributed up to 30% of the phosphorus loading of the receiving reservoirs. Quayle *et*. al., 2010 concluded that the elimination of phosphate from South African detergents is both beneficial and desirable as this will assist in the reduction of phosphate loading in rivers and dams. Wastewater treatment works that are not capable of removing phosphorus in their plants will benefit from this action.

4.2. SOURCES OF NUTRIENTS GIVING RISE TO EUTROPHICATION IN SOUTH AFRICAN WATERS

The main driving force to eutrophication is human population growth associated with economic and human activity impacts. Human activities such as industries, mining, settlements and agricultural activities produces products and by-products containing both nitrates (N) and phosphates (P) which are released into the aquatic environment through various pathways (Walmsley, 2000). Thornton et. al. (2013) defined eutrophication as the enrichment of lakes and reservoirs with plant nutrients such as nitrogen and phosphorus.

Wamsley (2000) further identified phosphorus as the key element or the fundamental cause of eutrophication in South Africa. Phosphorus is a growth limiting nutrient in aquatic ecosystems. It is an element that may be directly attenuated through the management of land-use practices or point source controls (i.e. there exists a direct relationship between the concentration of total phosphorus (TP) and the photosynthetic pigment chlorophyll-a (Chl-a). It is for these reasons that eutrophication management tools focus fundamentally on phosphorus (Rossouw *et al*. 2008). There are point and non-point sources of nutrients. Sewage and industrial effluents have been identified as the major contributors of phosphorus on South African waters. In domestic waste water human excreta and synthetic laundry detergents have been identified as the major source of phosphorus. Industrial wastewaters typically high in phosphorus include those generated from fertilizer production, feedlots, meat processing and packaging, milk processing and commercial laundries (DWAF, 1986).

Non-point sources of phosphorus include: effluent from non-sewered populated areas, urban runoff, and runoff from both cultivated and uncultivated land, groundwater and both wet and dry atmospheric precipitation. Lake bottom sediment is also identified as a significant nonpoint source of phosphorus. Sediments do not only act as sinks of nutrients but also as a source (DWAF, 1986). Sources of Eutrophication are summarized in Table 1.

Table 1: Summary of sources of Eutrophication (DWS, 2017b)

Water Quality Issue	**Driver**	**Sources**
Eutrophication	• Wide-spread discharge of raw or inadequately treated municipal sewage. • Raw sewage overflows. • Diffuse runoff and drainage from fertilized	**Point Source:** • Dysfunction in many municipalities, manifested by any or all of the following shortcomings: inadequate financial and operational planning, inappropriate financial prioritisation, lack of pro-active infrastructure maintenance, inadequate problem reporting/response systems, lack of appropriate technical personnel and financial shortfalls.

Water Quality Issue	Driver	Sources
	cultivated land. • Nutrients leaching from faecal sludge in pit latrines / septic tanks in non-sewered sanitation technologies polluting water resource (both surface and groundwater) • Mining activities	• Inadequate cooperative governance and cross-regulatory interfaces between DWS and the affected municipalities, the Department of Cooperative Governance and Traditional Affairs (COGTA) and various other government institutions. **Diffuse/Non-Point Source** • Non-sewered leachate from groundwater and informal settlements. • Inappropriate farming practices, such as over-fertilisation, inappropriate tillage, over-irrigation and encroachment on or destruction of riparian buffer zones and wetlands. • Inadequate cooperative governance and cross-regulatory interfaces between DWS and the National Department of Agriculture, Forestry and Fisheries (DAFF) and its provincial counterparts and various other government institutions hinders the management of these phenomena. • Increased nitrogen levels in groundwater through the use of nitrogen-based explosives.

4.3. MAJOR CAUSES OF EUTROPHICATION IN SOUTH AFRICA

In natural lakes a distinction is sometimes made between 'natural' and 'cultural' eutrophication processes (DWAF, 2002). Natural eutrophication depends only on the local geology and natural features of the catchment, whereas, cultural is associated with human activities (anthropogenic) such as population dynamics (inadequately treated effluent from the WWTWs and industrial sector) and agricultural activities affecting the distribution of nutrient enriched waters (van Ginkel and Silberbauer, 2007; and Matthews, 2019). The causes of Eutrophication in SA are summarized in Table 2.

Table 2: Causes of Eutrophication

Natural cause	**Unnatural cause**
• Nutrient leaching from local geology and soils	• Atmospheric emissions of Ammonia (NH3) and nitrogen dioxide (NO2) resulting in increased loads of NH3 and NO2 in precipitation. • Increased nutrient loads in discharges from WWTWs. • Increased nutrient loads in agriculture and urban runoff. • Excessive nutrient loads in industrial wastewater. • Increased nitrate concentrations in groundwater resources due to feedlots, dairy farming and inappropriate onsite sanitation (*e.g. pit toilets)* at rural villages and towns frequently and abandoned well fields (CSIR, 2017).

The trophic status of surface water bodies can be classified by the level of nutrient enrichment as oligotrophic, mesotrophic, eutrophic and hypertrophic (ranging from minimum impact on water quality (oligotrophic) to maximum impact water quality (hypertrophic). The tropic status of SA water bodies assessed in 2016/17 indicated approximately 26.02 Oligotrophic, 12.7 Mesotrophic, 26.6 Eutrophic and 34.5 per cent hypertrophic. Further water quality degradation is confirmed by the 2002-2012 trophic status indicating approximately 27.3 Oligotrophic, 5.9 Mesotrophic, 18.3 Eutrophic and 48.3 per cent hypertrophic (Matthews, 2019). The current trophic status in SA's Water Management Areas (WMA) is summarized in Figure 2.

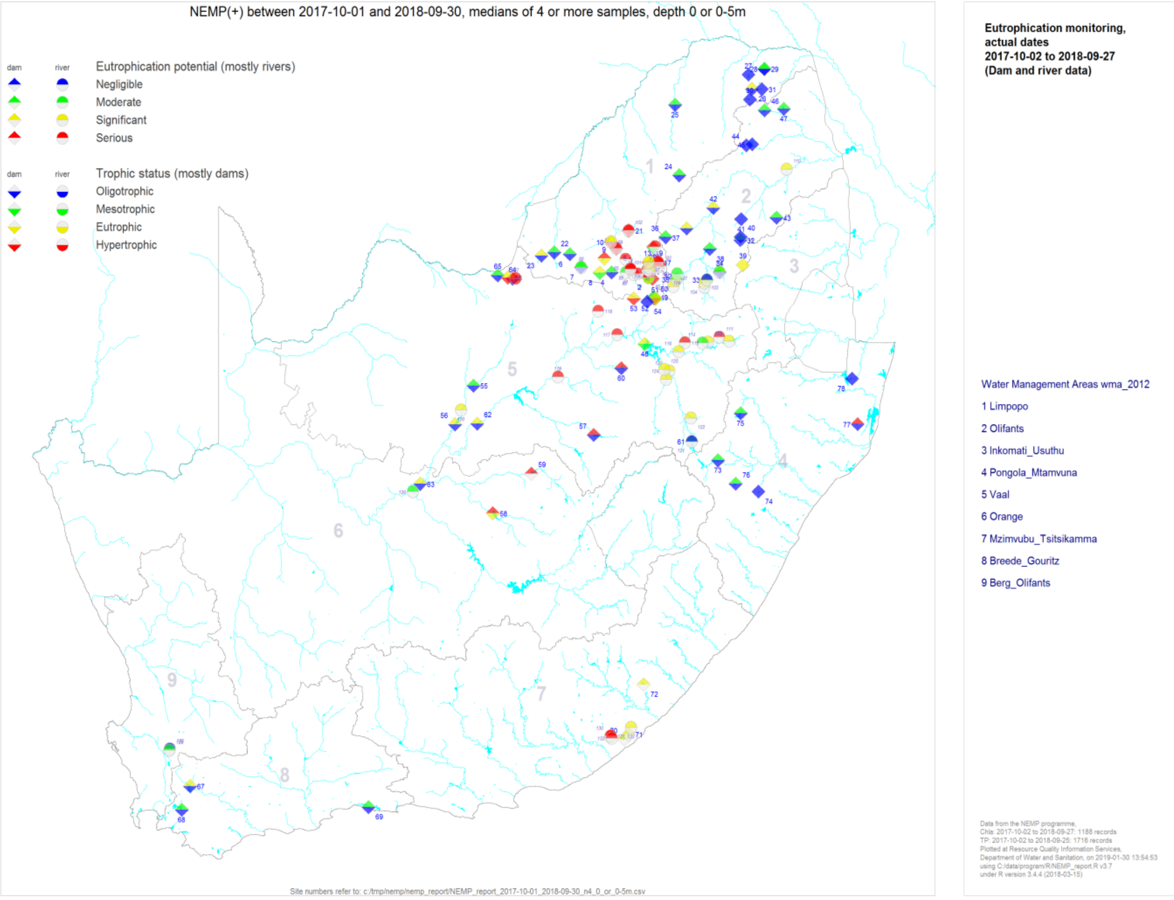

Figure 2: Summary of the trophic status and eutrophication potential for hydrological year 2017/18 (DWS, 2018).

Nutrient cycle indicating causes of eutrophication is summarized in Figure 3.

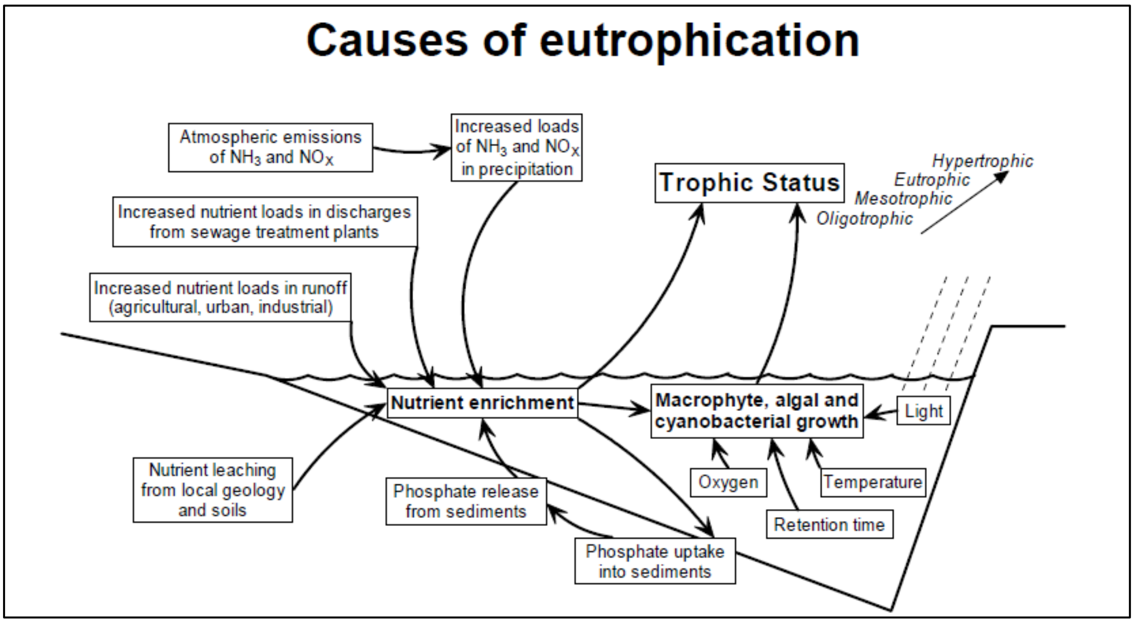

Figure 3: Nutrient cycle indicating causes of eutrophication (DWAF, 2002)

4.4. IMPACTS OF EUTROPHICATION IN SOUTH AFRICA

Eutrophication is the result of several external factors, especially input rates of nutrients such as Total Phosphate. Failing to control increased levels of nutrients such as nitrogen (N) and phosphates (P) in the ecosystem leads to eutrophication and increased weed and algal growth in water resources. Phosphorus is confirmed to be an eutrophication management elements and the effective removal of P will improve the eutrophic status of the aquatic health; while N in wastewater is said to be easy to attenuate (van Ginkel and Silberbauer, 2007; and Harding, 2017). Eutrophication is of great concern because of its negative impacts i.e. ecological such as deterioration of water quality and biodiversity loss, human and animal health, aesthetic and recreational impacts, all these impacts have significant economic impacts (Figure 4).

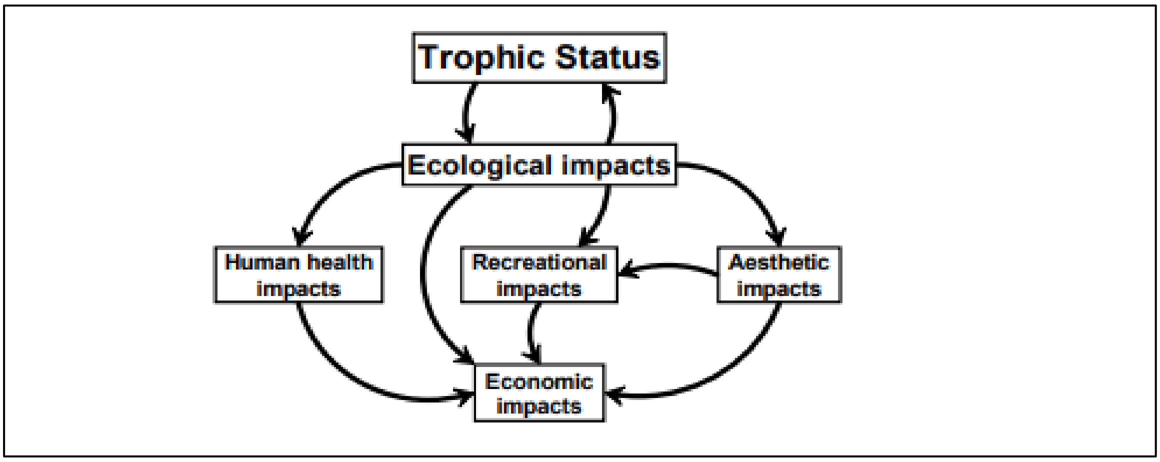

Figure 4: Summary of potential negative impacts of eutrophication (DWAF, 2002)

Table 3 summarizes situations resulting from the impacts highlighted in Figure 4.

Table 3: Impacts of Eutrophication

Impacts	**Situations resulting from the impacts**
Ecological Impacts	• Disturbances to biodiversity
Human and Aesthetic impacts	• Odour and taste problems • Morbidity and mortality (due to potentially-toxic cyanobacteria) • Malaria outbreak
Recreational Impacts	• Decreased recreational use • Decreased access to waterways
Economic Impacts	• Increased water treatment costs • Stock losses • Corrective action costs • Loss of property value

i. <u>Ecological Impacts</u>

Macrophyte invasions and alga and cyanobacteria blooms are direct impacts on the health of an aquatic ecosystem (DWAF, 2002). The rate of algal bloom and macrophytes growth impedes the rate of indigenous habitat and biota, impacting negatively on the value of goods and services provided by the water resources. Most of rural communities depend on the goods and services provided by the water resources for living *i.e*. crops and livestock, which has a fraction adding to the Gross Domestic Product (GDP) of the country. Changes of ecological community structures and loss of biodiversity, resulting in fish and invertebrate mortalities are constantly experienced in the hyper-eutrophic dams *e.g.* the Hartbeespoort and Rietvlei dams (Jones-Lee and Lee, 1984 and Mitchell and Crafford, 2016).

ii. <u>Human Health Impacts</u>

Rivers that are located downstream of eutrophic water bodies are likely to have large number of cyanobacteria that are discharged from the outflow of these water bodies (e.g. lakes). Where potable water supplies have been provided to residents of rural areas that are located downstream of eutrophic lakes, water supplies usually unreliable and insufficient; this forces residents to revert to traditional ‘contaminated’ river sources for their domestic uses (Oberholster, 2008). This has major health risk due to poor water quality, as well as being contaminated with cyanobacteria and other water-borne diseases (Oberholster and Ashton, 2008).

iii. <u>Aesthetic Impacts</u>

Decaying toxic algae releases toxins in the raw water, associated with human health problems such as unsightly scums, odour and taste problems.

iv. <u>Recreational Impacts</u>

Decreased recreational use, such as no more swimming, boating and fishing due to bad odour when algal blooms die off; and plant cover also decreases access to waterways. There is evidence from previous studies that eutrophication has a major impact on the domestic and recreational use, for example, the noticeable effect on the prices of residential properties adjoining Hartebeespoort Dam (van Ginkel, 2007).

v. <u>Economic Impacts</u>

Agriculture is the main water user sector in SA, approximately 60% of water use compared to the other water users such as domestic, industrial and mining sector. Agriculture is also a main pillar in the economic hub of the country. Poor water quality impacts on crop yields and makes crops vulnerable to import restrictions from countries with strict quality standards (DWS, 2017b). High levels of nutrients and algal blooms in the Breede and Berg River systems is a critical risk threatening international markets in the Western Cape (Cullis *et. al.*, 2018). The severity of algal blooms causes contamination in the rivers, resulting in livestock and wild animal deaths in the Kruger National Park, SA (van Ginkel, 2011); a big threat to the tourism, recreation and property value sectors.

Maintenance costs increase due to increasing algae. Excessive algae have the potential to clog the water treatment plants filters and the irrigation systems. The cost of cleaning the blocked filters and systems gets translated to water users, unnecessarily adding to the production costs of the water users. The water treatment costs are passed on to the consumer through the increased costs of the Water Services Provider in municipalities.

4.5. MONITORING

4.5.1. The Monitoring Networks

The NWA (Chapter 14) requires that the Minister of Water Affairs (Water and Sanitation) establish national monitoring systems for the collection of appropriate data and information that is adequate and responsive to the present and future challenges of efficient management of the country's water resources.

DWS runs a number of monitoring programmes as stipulated in the revised National Water Resources Monitoring Networks (DWS, 2016 and DWS, 2017a) as the following:

- Hydrological – measuring river flows, dam levels and evaporation;
- Geohydrological – measuring groundwater levels, chemistry and isotopes;
- Surface Water Quality – chemical, microbial, **eutrophication**, radioactive and toxicity; and
- Biological – aquatic ecosystem health such as River Ecosystem monitoring Programme (REMP).

The purpose of these monitoring programmes is to ensure that water resources are managed and protected, according to protection measures stipulated in the NWA. The existing monitoring programmes have been reviewed with the intention to optimise monitoring and the implementation developed in order to address the future requirements for water resources monitoring for South Africa. Many of South African impoundments still exhibit high nutrient enrichment and eutrophication related problems (van Ginkel *et. al.,* 2000)

4.5.2. National Eutrophication Monitoring Programme (NEMP)

The NEMP is one of the series of the National Water Quality Monitoring Programmes developed in 2002 and managed by the DWS as the custodian of water and is designed for the following objectives:

- To give a national perspective on the current trophic status of monitored sites;
- To determine the nature of eutrophication problems in SA Aquatic systems; and
- To determine the trend in trophic status in order to inform planning.

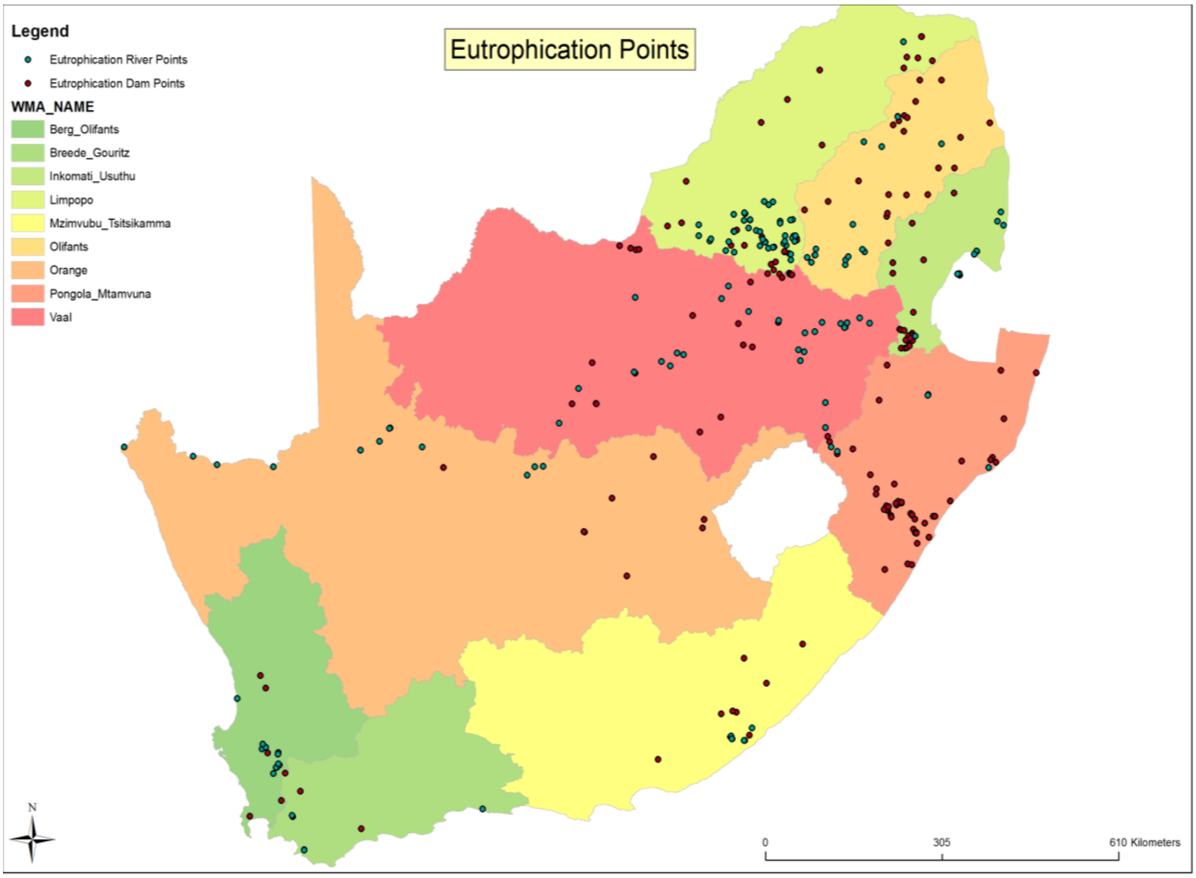

Figure 5: Current spatial network coverage of NEMP eutrophication sites in South Africa

To date the NEMP programme has 451 registered sites with 320 dams/lakes and 131 river sites being active (Figure 5). The Data used for Figure 5 were extracted from the Water Management System (WMS) database of the South African Department of Water and Sanitation (DWS). DWS in collaboration with other sectors such as the Catchment Management Agencies, Municipalities, Water User Association (Irrigation Boards) and the Water Boards are responsible with monitoring the NEMP sites, generating relevant data and information for the whole water sector. The NEMP sites are distributed across the country and samples are collected from reservoirs, lakes and rivers. Data and information collected is made available to different stakeholders and for different purposes such as research, compliance and enforcement and planning.

Despite the success of the NEMP programme, there has been a decline in monitoring over the years due to challenges such as lack of funds, lack of capacity (human resources) and non-functional and under capacitated laboratories. In addition to other interventions to enhance monitoring of eutrophication and in particular cyanobacteria blooms that pose a significant health risk in the interests of public health and safety, and also adapt to monitoring utilising applications made feasibly by recent technological advancements.

Satellite remote sensing has been identified as a potential tool to greatly enhance the NEMP programme.

4.5.3. Integration of Earth Observation in to the National Eutrophication Monitoring Programme (EONEMP)

The project entitled, "Integrating earth observation into the National Eutrophication Monitoring Programme (or EONEMP)", made use of satellite earth observation (remote sensing) for the monitoring of cyanobacteria blooms and eutrophication in South Africa's large- and medium-sized fresh water bodies. The chlorophyll-a (chl-a) estimates from satellite have been integrated into the WMS of DWS in order to supplement and fill information gaps in the NEMP (Matthews, 2019). The project is collaboration between the WRC, Department of Science and Technology and the Department of Water and Sanitation.

Satellite remote sensing has been identified as an important tool to greatly enhance NEMP which is run by the Directorate: RQIS. Remote sensing affords the opportunity to monitor at an unparalleled spatial scale, frequency and consistency. Given the widespread occurrence of cyanobacteria blooms, and the high risk these post to human and animal health, there is significant impetus for embracing satellite-based technologies for continual monitoring and for the protection of public health.

Among others, the project saw the development of an online near real-time monitoring service that uses satellite remote sensing to provide information about harmful cyanobacteria and algal blooms in South Africa's large water bodies to the public. The information is aimed at reducing the exposure of humans to cyanobacteria blooms that may result in a variety of harmful health effects, and reduce the incidence of animal poisonings. The presence of algae and cyanobacteria is also a useful indicator of possible upstream nutrient pollution from wastewater treatment works and other sources.

. The remotely sensed estimates were integrated into the national WMS database, for the full potential of satellites monitoring to improve data and fill information gaps. This is towards improving the management and response to cyanobacteria blooms, eutrophication, and outbreaks of invasive aquatic macrophytes in South Africa's surface water resources. The value of satellite data is dependent on sufficient in-situ surface measurements of chl-a and phytoplankton, so accurate monitoring from space is reliant on the continuation of the NEMP (Matthews, 2019). There would be a substantial value in DWS adopting the recommendations outlined by the EONEMP project completed in 2018, in order to optimize the existing NEMP, which is not the case currently due to budget constraints. EONEMP would have complemented the already existing NEMP and provided an opportunity for more sites to be monitored that were not included under NEMP.

CHAPTER 5 – MEASURES IN PLACE TO MANAGE EUTROPHICATION

Both in South Africa and globally it has been recognised that managing water quality requires a systems-based approach, coupled with adaptive management techniques and supported by strong partnerships amongst government, civil society and the sector (DWS, 2017).

5.1. WATER RESOURCES PROTECTION MEASURES

In South Africa (SA), as mandated by the National Water Act (NWA), Act 36 of 1998, Chapter 3 deals with the protection of the country's water resources. Water resource protection measures are categorized into Resource Directed Measures (RDM) and Sources Directed Control (SDC). Three components of RDM are water resource classification, RQOs and the Reserve, developed to implement the NWA on matters relating to water resource protection, aligned to the NWRS-2. The SDC entails pollution prevention and emergency incidents and should be aligned to catchment management strategies (NWA, 1998). The SDC measures are about managing and controlling activities such as the abstraction of water and disposal of effluent / pollution sources (point and non-point / diffuse sources of pollution) impact on the water resources. Pollution sources are amongst other, discharges (waste and wastewater) from industries, runoff from agricultural practices and untreated sewage from domestic / local government sector Waste Water Treatment Works (WWTWs).

Regardless of the RDM and SDC measures being in place, water quality (without the exception of eutrophication) has not improved since. One of the reasons could be that measures in place are currently not fully implemented due to budget constraints, lack of data / data gaps and lack of adequately skilled personnel.

5.2. DWS REGULATORY MECHANISMS

Water uses stipulated in Chapter 4 of the NWA culminates into different water impacts if not regulated (controlled and managed) properly. Water use regulation is meant to ensure effective and efficient delivery of sustainable water services, according to the WSA. The main aim is to clarify the requirements and obligations of water services institutions, protecting the public from a potentially unsustainable and unsafe water services. DWS's regulatory interventions to prevent drinking water and water resources pollution at large include the following:

i. Water Use Authorization

Control and management of water can be exerted over an activity through the water use authorisation for that particular activity such as issuing a general authorisation or a water use licence. Activities that lead to nutrient enrichment (eutrophication) are often water use activities, as defined in Section 21 of the NWA, which can be controlled by the enforcement of water use authorisation requirements or conditions.

ii. Blue Drop and Green Drop certification programme

The incentive-based Regulation measures in SA were initiated in 2008 and are characterized by two (2) programmes such as the Blue Drop and the Green Drop Certification. The Blue Drop Certification programme is designed to manage the drinking water quality management regulation, whereas the Green Drop Certification programme is intended to identify, reward, ensure and encourage excellence in wastewater management (DWA, 2012 and 2013).

The DWS assesses and scores the municipal WWTW across SA and use the baseline to develop Risk-Based Regulatory Approach. The programme provides feedback and progress pertaining to the current status and risk trends of the municipal, public and privately owned WWTW. Based on the outcome of this evaluation, guidance is provided by DWS to municipalities to support them with adhering to the license conditions of the WWTWs (DWA, 2012 and 2013).

The Green Drop RISK PROFILE Progress Report for 2014 (as assessed by the Green Drop Progress Assessment Tool (PAT), is the product of a 'gap' year whereby progress is reported in terms of the improvement or decline in the risk position of the particular wastewater treatment facility, as compared to the previous year's risk profile. The municipalities, Public Works, Department of Environment and selected private works such as SANParks, have participated in the PAT assessments in 2014. The overall results indicated that the municipal industry as a whole has not managed to contain and turnaround the risk, as the majority of plants are in high risk. According to the NW&SMP (2018a and b), approximately 56% of over 1150 municipal WWTWs and 44% of the 962 Water Treatment Works in the country are in a poor or critical condition DWS; with 11% of these infrastructures completely dysfunctional. The green Drop criteria allow the regulator (DWS) to follow-up with the municipalities to identify and prioritize the critical risk areas in order to take corrective measures to mitigate the risks.

The Blue Drop and the Green Drop assessments are currently not happening due to challenges ranging from lack of funds to lack of capacity. However, the Integrated Regulatory Information Systems (IRIS) is currently in place and is meant to integrate all the DWS regulatory tools in place such as the Blue and the Green Drop Certification, classification of WWTWs, water and wastewater Compliance and Enforcement.

iii. Command-and-control mechanisms

Regulatory measures seek to place direct controls on the behaviour of dischargers in order to manage eutrophication. Ways to place direct controls among others include:

- Input restrictions into the production process (e.g. banning phosphate containing soaps);
- Technology controls (enforcing certain minimum technology requirement, e.g. activated sludge treatment);
- Output controls (e.g. effluent discharge standards);
- Zoning (restricting activities to certain geographical areas, thereby influencing where discharge/ pollution occurs

iv. Economic instruments

Economic instruments make use of economic rationality and market forces to change discharge behaviour.

These instruments introduce economic incentives / disincentives to affect dischargers' decision-making. Common example in South Africa is the proposed Waste Discharge Charge System (WDCS).

v. Waste Discharge Charge Systems

The Department of Water and Sanitation is in the process of finalizing the development of a WDCS to promote waste reduction and water conservation. It is a tool that will be used in future to support existing water quality management initiatives. It forms part of the Pricing Strategy and is being established under the NWA, 1998 (Act 36 of 1998).

The WDCS is based on the polluter-pays principle and aims to:

- Promote the sustainable development and efficient use of water resources,
- Promote the internalisation of environmental costs by impactors,
- Create financial incentives for dischargers to reduce waste and use water resources in a more optimal way,
- Recover the costs of mitigating the impacts of waste discharge on water quality.

The Total Maximum Daily Loads (TMDLs) of nutrients (Phosphorus) are needed to inform the WDCS, i.e. control the discharge of pollutants into the water resource. According to Harding (2015a), TMDLs OR Pollutant Load Allocation is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards. The WDCS is meant to encourage water users to change their behaviour i.e. meeting the required wastewater standard before discharging into the water resources.

vi. Persuasive instruments

Persuasive instruments are commonly the non-regulatory, non-economic instruments deployed in the management of eutrophication. Typical examples include provision of Ecosystem / Ecological Goods and Services, promotion of catchment partnerships (co-operative governance), education, awareness raising, self- regulation and voluntary agreements (*e.g.* certification and labelling).

5.3. POLICY FORMULATION AND DEVELOPMENT OF BEST MANAGEMENT PRACTICES

i. Guidelines on prevention, management and control of eutrophication

The Department of Water and Sanitation developed three sets of guidelines for Prevention, Management and Control of eutrophication which are in the approval process for implementation.

The three sets of guidelines are:

- Eutrophication: prevention, management and control: an introduction
- Operational Guideline for Best Eutrophication Management Practices
- Operational guideline to develop a Catchment Eutrophication Management Strategy

The guidelines are aimed at DWS managers, water user associations, catchment management Agencies (CMAs) and local authorities who have mandate for developing strategies and specific interventions to manage eutrophication problems, either at local or catchment scale.

ii. **<u>Revision of SA's Water Quality Management Policies and Strategies</u>**

In response to the country's need to take an improved integrated approach to water quality management, the Department of Water and Sanitation initiated a project in 2016 to revise its current Water Quality Management (WQM) Policies and Strategies. Factors necessitating the need included; lack of effective implementation of the current WQM policies (*e.g*. WQM policies and strategies in SA -1991, Resource Directed Management of water Quality – 2006 *etc*.), emergence of new water quality challenges and an increase in non-compliance to water quality objectives (RWQOs).

5.4. IN-LAKE EUTROPHICATION MANAGEMENT PRACTICE PROJECTS

The DWS in partnership with other key relevant stakeholders initiated the development of in-lake eutrophication management projects in some areas within the country with the aim of rolling them to other areas that experience similar eutrophication problems. These initiatives will serve as lessons learned in this project and were rolled out as follows:

- Hartbeesport Dam Integrated Biological Remediation Programme (HDRP), also known as the Harties Metsi-a-Me Programme: This was an over-arching project which started in 1996 and ended in 2013 (Phase 1), and was based on the Integrated Biological Remediation Programme that looked at a wide variety of short-term and long-term methods to control the eutrophication status of the Hartbeespoort Dam. The Resource Management Plan for Hartbeespoort Dam was based on the basic principle of ecosystem improvement for both human and environmental needs. The rehabilitation process of web reconstruction supported the development of spirogyra algae and indigenous aquatic plants, which utilises more nutrients and in return suffocate the notorious blue-green algae.

  The work done in Phase I (Mitchell and Crafford, 2016) has raised some flags, questions and hypothesis, which led to the following recommendations amongst others, in support of Phase II of the project:

  - The Minister to appoint a broad-based scientific committee to identify priority areas for attention.

- Phase 2 of the HDRP needs to focus on the catchment upstream of the dam, specifically on improving the quality of the water flowing into the dam. The WDCS has been piloted in this catchment and this provides the opportunity to implement the system. Provision for the implementation of the gazetted WRCS.

- Certain of the in-lake activities started in Phase 1 should be continued. But the programme should be broadened to effectively address the quality of the inflowing water in order to reduce the loading of plant nutrients. This will require increased funding.

- The programme should be set within an adaptive management framework, in order to develop the vision and translate it into achievable objectives.

- A provision for a monitoring programme focusing on progress towards achieving the required objectives.

- Capacity building / training to manage reservoirs - the revitalization of reservoir limnology as a profession: SA relies on reservoirs to balance the supply of water with the demand in the face of variable precipitation, so the country needs to develop the capacity to manage these reservoirs (Harding, 2015b).

- It is recommended that the 1 mg/ℓ P standard for effluents discharged into designated sensitive catchments by wastewater treatment works be reviewed in the light of the capabilities of modern technology.

- Solar-Powered Reservoir Circulator / Solar-Bee: floating solar-powered reservoir long distance circulation pump system used to mix water columns and greatly accelerates the biological and solar processes that clean up water. Both horizontal and vertical circulation patterns are created for improved distribution of oxygen, an enhance water clarity, elimination of cyanobacteria (blue-green algae) blooms and reduce nuisance aquatic weed growth. In 2018, Tshwane Metropolitan Council installed these plants at Rietvlei Dam as a step towards finding solutions to in-lake eutrophication. It has been proven to improve water quality (increase oxygen levels throughout the dam) and reduced algae toxins (high phosphorus reduction) in the water. The system is very economical, requires minimum maintenance, and can operate day and night using only solar energy.

- WRC Bio-manipulation Project to determine the potential impact of fish-harvesting on improving eutrophication conditions. Bio-manipulation is well known as a management tool for eutrophic systems. WRC (Project K5/1918) funded project on 'Food-web interactions in South African Reservoirs', a study by Harding and Hart (2013), looked into the food-web structure in the hypertrophic Rietvlei Dam based on stable isotope analysis and its implications for reservoir bio-manipulation. The study concluded that in order to manage eutrophic South African reservoirs or impoundments the 'top-down' bio-manipulation of a reservoir food-web is a counter-measure suggesting that nutrient control remains the paramount focus for restoring eutrophic lakes rather than trying to deal with the symptoms (endorsing the maxim 'prevention is better than cure').

CHAPTER 6 - GAP ANALYSIS AND REQUIRED INTERVENTIONS

6.1. GAPS

The processes to deal with eutrophication in SA have been hindered by issues of skills migration (human capacity), the poor state of water-related infrastructure, decay and operational mismanagement of municipal wastewater treatment facilities, and lack of progress with governance structures (e.g. finalization of the establishment of the CMAs).

6.1.1. Lack of Capacity and understanding

The 2002 survey has indicated that DWS (then DWAF) regional offices currently lack the capability (relevant skills) to implement desirable eutrophication management programmes for water resources under their jurisdiction, as desired by published policy and prescribed by legislation (the National Environment Act and the National Water Act) (DWAF, 2003). Relevant career prospect such as lake and reservoir limnology is a scare skill, which needs to be addressed (Harding, 2015b). However, addressing point source loading is the principal challenge and which will take many years to achieve success.

6.1.2. Delay in the Implementation of the Protection and Regulatory Measures (Failure to implement interventions effectively)

Delay in the implementation of the regulation interventions such as RDM measures, Blue-Drop/Green-Drop Certification, WDCS and the review and optimization of the monitoring networks is also linked to lack of funds. There will be no point in developing a complex strategy if the legislative framework cannot be enforced. For example, WRC as the departmental research institute completed a project "Integration of Earth Observation in to the National Eutrophication Monitoring Programme (EONEMP)" (Mathews, 2019). After the launching of the project in 2019, the documents were handed to DWS for the uptake but DWS has no capacity to take over the project due to budget constraints and the fact that the amount of variables (two to be specific) being analysed are not aligned to DWS NEMP which has about 45 variables. The DWS and the WRC have an understanding that the implementation of completed projects should be understood by both institutions and DWS should prioritize and facilitate the uptake. In terms of WDCS, Harding (2017) suggested Catchment level of identification of sources of nutrients in terms of loads, especially phosphates and that an individual polluter must get an allocation of waste discharge levies, in relation to the pollution caused.

6.1.3. Applied Research, Technology and Intervention

Several projects related to reservoir, lake or eutrophication were funded and commissioned by the Water Research Commission (WRC), as the SA's primary funder of aquatic science related studies. South Africa has no total mean daily load (TMDL) equivalents or other nutrient loading-based protections in place for any of its reservoirs, although the feasibility of employing the TMDL approach in South Africa is being assessed (Harding 2015b). In addition, lack of resource water quality model enhances failure to implement RDM interventions effectively.

6.1.4. Monitoring gaps

Recent gaps in data have been attributed to a lack of funds or budget cuts. The satellite estimates as an additional monitoring recommended supplementing NEMP, but it comes at a cost (Matthews, 2019). Through the integration of near real-time data into the NEMP, In addition to other monitoring tools such as water clarity measurement using the Secchi disc, which provides good data that can be easily collected by water agents, citizens, and staff. Secchi disc tool data collection can be used to ground truth satellite observations. Continuous running of the monitoring programme such as NEMP is essential in achieving the management of eutrophication, yet currently not running due to travel constraints for data collectors.

Furthermore, delays in contracting accredited laboratories to conduct analysis, lack of technically competent staff as well as governance challenges further hamper the operations of the monitoring programmes (DWS, 2017a). There is a need to expand the current monitoring network due to an increasing demand for reliable data and information, and the fact that the majority of impoundments in South Africa do not have routine eutrophication monitoring sites. Monitoring is a tool to assess implementation, for example, the only way to check if WDCS and RQOs are being complied with is through monitoring.

CHAPTER 7 - CONCLUSION

With 62% of South Africa's largest dams being eutrophic or hypertrophic the need for nutrient attenuation interventions or remedial interventions is long overdue and is likely to be extremely costly. Either way, it will be disastrously expensive not to intervene. In South Africa, eutrophication has been recognized as a priority water quality problem for over 30 years, and with wastewater effluents contributing substantially to the situation. The policy and approach to eutrophication control has been inadequate for over the last 20 years.

An urgent need to rectify this situation was therefore identified, that led the DWS to revise, update and consolidate its policies and strategies and came up with the Integrated Water Quality Management (IWQM) Policies and Strategies (2016 and 2017), the NWRS-3 (2019/20) and the NW&SMP (2018).

Deteriorating water quality is a major constraint to economic and social development; it reduces the sustainability of the available resource, and impacts significantly on the cost of treating water. Urgent measures such as upgrading of the WWTWs must be taken as a priority to protect and restore SA's water quality.

Managing catchments such that levels of eutrophication do not exceed thresholds above which problems are encountered, 'eutrophication capacity" should be a primary focus of South African water resource management. In cases where dams have become eutrophic, there is a need to attenuate the loading of nutrients in order to reverse the trend. The solution to combat eutrophication is complex and no single approach applicable to solve eutrophication challenges, therefore integration of series of interventions ranging from nutrient load reduction strategies to aquatic ecosystem rehabilitation such as sediment removal and ecosystem. For example, point source pollution control efforts alone have not been completely successful in addressing eutrophication; in addition storm water management has been considered to deal with non-point sources of pollution. Both approaches have included the establishment of numeric goals (standards), now the RQOs that can be achieved using available technologies or engineering approaches.

Reduction of nutrient load seem to be a way to go for a long term solution compared to approaches to combat eutrophication symptoms like harvesting algal bloom and macrophytes.

Catchment Best Management Practice initiatives - eutrophication problem persists despite the application of laws and technologies. Knowledge of the rate of phosphorus loading, in relation to the trophic status of a particular reservoir, will guide catchment managers in setting limits on nutrient discharges at the catchment level. In so doing the eutrophication-associated risks to ecosystem (the catchment) and human and animal health may be minimized. DWS supports a protocol to undertake catchment scale water quality assessment studies to support the development of catchment management strategies. Implementation of the existing measures such as the RDM (Reserve, classification and RQO's) should be encouraged and maintained.

A lack of data and information resulting from weak monitoring systems poses high risks to decision making and planning and should urgently be addressed by repairing and maintaining measuring infrastructure, adopting new monitoring technologies (such as Earth Observation Remote (Satellite) Sensing), and improving data management and distribution.

Application of the latest research, innovation and development in water-less/alternative water and sanitation systems should be implemented urgently to address excess demand.

Capacity Building – A need was identified to develop eutrophication Capacity Building approach to generate a wider understanding of the causes and consequences of and remedial options for eutrophication in South Africa. Resolving eutrophication issues requires informed role players, and that can be achieved through dedicated public education and social consciousness. There is a near-total lack of the structures, skills and planning needed to address water quality issues. The development of capacity building programme should support all other activities i.e. training, education and awareness campaigns. The programme should assist in creating a practical and practicable strategy, and importantly also for supporting the sustainable implementation of an effective strategy.

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