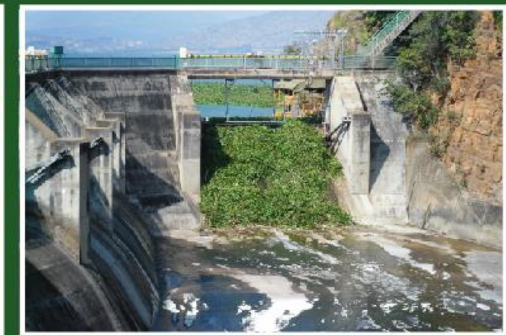
EUTROPHICATION MANAGEMENT STRATEGY FOR

– SOUTH AFRICA 2023 –



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water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

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DEPARTMENT OF WATER AND SANITATION

EUTROPHICATION MANAGEMENT

STRATEGY FOR SOUTH AFRICA

Edition 2
February 2023

PROJECT REPORT NUMBER 4.2
SOURCES DIRECTED STUDIES REPORT NUMBER RDM/EMP&S/00/IHS/SDS/0521

MAIN COVER PAGE:

Photos on the cover page were kindly supplied by Mr Petrus Venter of the Department of Water and Sanitation.

Main photo (taken on 16 May 2012)**:**

Excessive water hyacinth, and green and blue-green algae collecting behind a floating biomass retaining barrier, which extends to a depth of ±7 m below surface, in the upstream vicinity of the Hartbeespoort Dam wall. The buoyed barrier, visible further upstream, is the safety barrier that limits recreational access too close to the dam wall.

Insert photo, bottom-left (taken on 26 January 2010)**:**

The release of nutrient-laden, green in colour algae-rich water from a full Hartbeespoort Dam through sluices in the dam wall.

Insert photo, bottom-middle (taken on 5 May 2011)**:**

The removal of excessive water hyacinth and debris from the Hartbeespoort Dam surface over one of the sluice gates.

Insert photo, bottom-right (taken on 4 February 2013)**:**

Excessive primary production in the vicinity of Estate D'Afrique, downstream of the Hartbeespoort Dam wall.

We thank Mr Venter for giving us permission to use his photos on the cover of this document.

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2	RDM/EMSSA/00/IHS/SDS/0220	Framework Report
3	RDM/EMSSA/00/IHS/SDS/0320	Situation Assessment and Gap Analysis Report
4.1	RDM/EMSSA/00/IHS/SDS/0421	Eutrophication Management Strategy for South Africa (Edition 1)
4.2	**RDM/EMSSA/00/IHS/SDS/0521**	**Eutrophication Management Strategy for South Africa (Edition 2)**
4.3	RDM/EMSSA/00/IHS/SDS/0621	Summary User-Friendly Report
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Foreword

The Department of Water and Sanitation (DWS) is proactively involved in programmes and innovations that continuously seek to improve the well-being of people and the environment; in partnership with the private sector and civil society to secure water that is fit for use for all. To this end, DWS has developed the Eutrophication Management Strategy for South Africa (EMSSA) for effective management of eutrophication to protect aquatic eco-systems and secure water resources that are fit-for-use.

Increased incidents of nutrient enrichment of water resources constitute a threat to all socio-economic water uses. The EMSSA, therefore, seeks to propose solutions for all the identified existing nutrient enrichment challenges, gaps, and burning issues to achieve the Sustainable Development Goals (SDGs) by 2030. This reinforces government's commitment to creating a conducive strategy that ensures political support and the introduction of a paradigm shift in dealing with eutrophication impacts.

The EMSSA has identified key actions that need to be implemented in maintaining and improving the country's resource water quality. Firstly, amongst the key identified actions is the need to address the excessive enrichment of water resources with nutrients (such as nitrogen and phosphorus), emanating from land use activities from industries, mining, agriculture, and dense settlements (diffuse run-off) and from the wastewater treatment works. Secondly, ensuring fitness-for-use of receiving water resources through the implementation of adaptive, systems-based eutrophication management at catchment level, and adjusting source control measures such as discharge standards that impact on the trophic status of receiving water resources.

Implementation of this strategy will require a collaborative effort from the sector partners being government and the private sector as we work towards improved water resources management. The strategy is part of a suite of tools required by the Integrated Water Quality Management Strategy (2017) and the National Water Resource Strategy to begin a water quality revolution that will enable partners to achieve a radical transformation in the water and sanitation sector regarding eutrophication management and pollution prevention.

Dr Sean Phillips

DIRECTOR-GENERAL:
DEPARTMENT OF WATER AND SANITATION

Departmental Approval

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Executive Summary

"Eutrophication" is a traditional ecological term used to describe the process by which a waterbody becomes enriched with plant nutrients. During this process, the waterbody accumulates organic matter and progressively changes its character from that of a deep waterbody to that of a wetland and, ultimately, to that of a terrestrial system – a process that is also likely to cause changes to the original flow path or morphology of watercourses. Eutrophication, therefore, is a term that is primarily associated with the process of natural ageing of lakes. Naturally occurring eutrophication is not reversible and continues for the lifetime of a waterbody, albeit at a slow rate. However, over the past ±100 years, human influences have greatly accelerated the rate of enrichment, thereby shortening the lifespan of waterbodies. In contrast to naturally occurring eutrophication, human induced eutrophication (also called *"anthropogenic eutrophication"*), is reversible – albeit at a cost. **This document – *i.e.,* the *"Eutrophication Management Strategy for South Africa"* – primarily deals with the management of anthropogenic eutrophication.**

The *"trophic status"* of water resources provides a measure of eutrophication and refers to the degree of nutrient enrichment in surface water resources and the amount of plant growth (or *"primary production"*) that can be sustained. Importantly, the trophic status of water resources is affected by multiple abiotic, biotic, physico-chemical and biological factors – not just by nutrient concentrations. Though some success has been achieved with the manipulation of abiotic, biotic and biological factors (mostly as a reactive measure to remediate eutrophic water resources), **the proactive control of nutrient-loading constitutes the primary means by which eutrophication is addressed worldwide; specifically, the control of excessive phosphorus and nitrogen loading.**

Anthropogenic nutrient enrichment is most evident in highly populated and developed areas where industrial effluent, water-borne sewage systems, wash-off from built-up areas, fossil fuel combustion, atmospheric fall-out and agricultural practices contribute to elevated loads of nutrients entering water resources. Eutrophication challenges in South Africa are exacerbated by insufficient wastewater infrastructure maintenance and investment; deteriorating ecological infrastructure; recurrent droughts, driven by climatic variation, and an unavoidable need for water resource development; inequities in relation to access to safe sanitation (against the backdrop of a growing population); water use regulation that is not consistently and/or adequately protecting South Africa's water resources; and a general lack of skilled water scientists and engineers.

To date, eutrophication in South Africa has been dealt with under broad guidance by the overarching Integrated Water Quality Management (IWQM) Policy and Strategy for South Africa, 2017 (and preceding general policies for water quality management and pollution control). Due to deteriorating water quality trends observed in recent years, specifically worsening occurrences of eutrophication, the need was identified to develop the first dedicated policy and strategy to explicitly and decisively address the escalating effects of excessive nutrient enrichment observed in many *"hot-spot"* water resources and catchments in the country. As such, the eutrophication management policy and strategy must–

- **apply nationally** (*i.e.*, to the country as a whole);
- address issues of **anthropogenic nutrient-loading** (*i.e.,* predominantly phosphorus and nitrogen-related), which might have the following adverse effects (if left unattended):
  - Lead to excessive nutrient enrichment in water resources (*i.e.* surface and/or groundwater resources);
  - Impair the resource quality of the country's water resources;
  - Give rise to water quality and nuisance concerns (thus negatively affecting property value, impairing fitness-for-use and restricting potential utility);
  - Cause eutrophication of surface water resources, and eventually the marine environment;

- Risk ecologically sustainable development; and
- Ultimately, have undesirable social and economic consequences.

Eutrophication management in South Africa subscribes to the IWQM Vision and Mission, *viz.*:

Vision: ***"Government, in partnership with private sector and civil society, secures water that is fit-for-use, for all, for ever."***

Mission: ***"To adopt a government-wide, adaptive and systems-based management approach, in alliance with the private sector and civil society, which will improve resource water quality, prevent pollution and ecological degradation, support ecologically sustainable economic and social development and allow an informed use of the nation's water resources."***

As such, eutrophication management has an important and specific role to play in the advancement of the above stated vision and mission. This role is embodied in the following goal for eutrophication management in South Africa:

Goal: ***"To manage eutrophication effectively in order to protect aquatic ecosystems and to secure water resources that are fit-for-use."***

A collage of different objectives offers further context to the Goal. This collage of different objectives can be grouped into two *"layers"* of objectives and associated policy statements, pertaining to eutrophication management. For practicality purposes, distinction is made between a *"first layer"* consisting of Chief Objectives, and a *"supporting layer"* consisting of Complementing Objectives for eutrophication management. Collectively, these two distinct *"layers"* of objectives for eutrophication management must strive to contribute towards realising the IWQM vision and mission and the national eutrophication management goal. These objectives are listed below:

The Chief Objectives for eutrophication management are to–

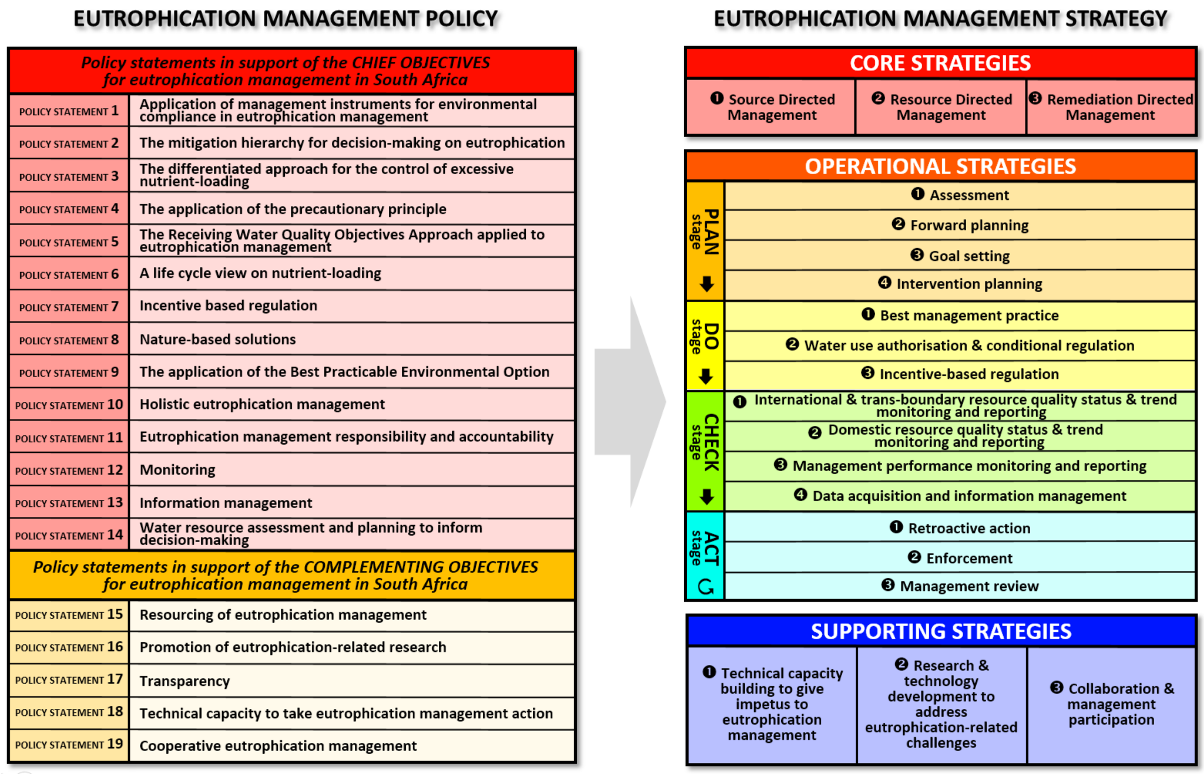
- limit anthropogenic nutrient-loading of water resources;
- reduce excessive primary production in surface water resources;
- protect aquatic ecosystems and their biological diversity;
- secure water resources that are fit-for-use on a continuous basis; and
- support ecologically sustainable development and justifiable socio-economic growth.

The Complementing Objectives for eutrophication management are to–

- resource eutrophication management, *inter alia*, by securing funding, providing human capital and equipping responsible parties;
- promote research in relation to management of eutrophication and control of anthropogenic sources of nutrient enrichment;
- promote management cooperation within and between government, private sector and civil society;
- promote transparency through stakeholder consultation, eutrophication-related communication and awareness creation; and
- facilitate capacity building and empowerment of role-players.

Fourteen technical and five supporting policy statements, which are regarded as most pertinent to eutrophication management in South Africa, were identified and developed. These policy statements (see the *"ROADMAP"* below) define ground rules, delineate intent, and specify desired outcomes with respect to the management of eutrophication.

Additionally, the strategy for management of eutrophication maps out overarching approaches for implementation that are aimed at realising all the strategic imperatives for eutrophication management. This strategy, *inter alia*, specifies authority (***"who?"***), prescribes approach and action (***"what and how?"***), and points to spatial (***"where?"***) and temporal (***"when?"***) scales of implementation.



The strategy is further structured into three types of interrelated and mutually supporting strategies for eutrophication management (see the *"ROADMAP"* above); these being–

- core strategies;
- operational strategies; and
- supporting strategies.

The **core strategies** focus on *"three faces"* or characters of eutrophication management, namely Source Directed, Resource Directed and Remediation Directed Management. They also highlight linkages among the three types of strategies.

The focus of the **operational strategies** is on operational management of eutrophication, and, thus, provide strategic guidance on multiple operational aspects of eutrophication management. These strategies are included by packaging them into an internationally accepted framework, known as the "**P**lan-**D**o-**C**heck-**A**ct" or P-D-C-A cycle.

The **supporting strategies** focus on strategic measures that support eutrophication management. These strategies were developed for technical capacity building to give impetus to eutrophication management; research and technology development to address eutrophication-related challenges; and collaboration and management participation.

The outlines of all these strategies (and their components) overlap and necessitate an integrated and comprehensive approach towards addressing anthropogenic eutrophication effectively in South Africa. Importantly, the implementation of measures to manage eutrophication need to take place in a holistic and cooperative manner, being cognisant of the requirements of integrated water quality management.

Policy and strategy implementation will be facilitated by the careful roll-out of (and monitoring and evaluation against) one or more implementation plans that must specify the following: actions; necessary resources (including budget, human capital and equipment, as may be required); and an implementation time schedule.

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List of Acronyms

	2-MIB	2-methylisoborneol
A	**AIA (2:2000)**	Access to Information Act, 2000 (Act No. 2 of 2000), as amended
	API	Application Programming Interface
	APP	Annual Performance Plan
	APTT	Anti-Pollution Task Team
B	**BARDENPHO**	BARnard DENitrification and PHOsphorus removal
	BC	Before Christ
	BMP	Best Management Practice
	BNR	Biological Nutrient Removal (also often referred to as the Bardenpho Process)
	BOD	Biological Oxygen Demand
	BPEO	Best Practicable Environmental Option
	BPG	Best Practice Guideline
C	**Capex**	Capital expenditure
	CARA (43:1983)	Conservation of Agricultural Resources Act, 1983 (Act No. 43 of 1983)
	CBA	Cost-Benefit Analysis
	Chl-α	Chlorophyll-α
	CMA	Catchment Management Agency
	CMF	Catchment Management Forum
	CMS	Catchment Management Strategy
	COD	Chemical Oxygen Demand
	CoGTA	Department of Cooperative Governance and Traditional Affairs
	CSIR	Council for Scientific and Industrial Research
D	**DAFF**	Currently DALRRD, previously the Department of Agriculture, Forestry and Fisheries
	DALRRD	Department of Agriculture, Land Reform and Rural Development
	DBE	Department of Basic Education
	DEA	Currently DFFE, previously the Department of Environment Affairs
	DEFF	Currently DFFE, previously the Department of Environment, Forestry and Fisheries
	DFFE	Department of Forestry, Fisheries and the Environment
	DHET	Department of Higher Education and Training
	DIN	Dissolved Inorganic Nitrogen
	DMRE	Department of Mineral Resources and Energy
	DNA	Deoxyribonucleic acid
	DO	Dissolved Oxygen
	DOH	Department of Health

	DPME	Department of Planning, Monitoring and Evaluation
	DPSA	Department of Public Service and Administration
	DPSIR	Driver-Pressure-State-Impact-Response framework
	DST	Currently DSI, previously the Department of Science and Technology
	DSI	Department of Science and Innovation
	DWA	Currently DWS, previously the Department of Water Affairs
	DWAF	Currently DWS, previously the Department of Water Affairs and Forestry
	DWS	Department of Water and Sanitation
E	**EIA**	Environmental Impact Assessment
	ELU	Existing Lawful water Use
	EMF	Environmental Management Framework
	EMI	Environmental Management Inspector
	EMF	Environmental Management Framework
	EMPR	Environmental Management Programme Report for mining
	EONEMP	Earth Observation National Eutrophication Management Programme
	EPA	United States Environmental Protection Agency
	EPMDS	Employee Performance Management and Development System
	ERA	Environmental Risk Assessment
	EWR	Ecological Water Requirement
	EWSETA	Energy and Water Sector Education and Training Authority
F	**FEPA**	Freshwater Ecosystem Priority Area
	FETwater	Framework Programme for Education and Training in Water
G	**GA**	General Authorisation
	GDP	Gross Domestic Product
	GDS	Green Drop System
	GEMS	Global Environmental Monitoring System
	GEMStat	Global Freshwater Quality Database
	GG	Government Gazette
	Global G.A.P.	Global Partnership for Good Agricultural Practice
	GN	Government Notice
	GNP	Gross National Product
H	**HETMIS**	Higher Education and Training Management Information System
I	**IDP**	Integrated Development Plan
	IHI	Index for Habitat Integrity method
	IRiS	Integrated Regulatory information System
	ISO	International Organisation for Standardisation

	IUCMA	Inkomati-Usuthu Catchment Management Agency
	IUA	Integrated Units of Analysis
	IWQM	Integrated Water Quality Management
	IWRM	Integrated Water Resource Management
L	**LCA**	Life Cycle Assessment
	LGSETA	Local Government Sector Education and Training Authority
	LIMCOM	Limpopo Watercourse Commission
M	**MDG**	Millennium Development Goal
	MERIS	Medium Resolution Imaging Spectrometer
	MISA	Municipal Infrastructure Support Agent
N	**NAEHMP**	National Aquatic Ecosystem Health Monitoring Programme
	NDMC	National Disaster Management Centre
	NDP	National Development Plan, 2030
	NEM	National Environmental Management
	NEMA (107:1998)	National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended
	NEM ICMA (24:2008)	NEM: Integrated Coastal Management Act, 2008 (Act No. 24 of 2008), as amended
	NEM WA (59:2008)	NEM: Waste Act, 2008 (Act No. 59 of 2008), as amended
	NEMP	National Eutrophication Management Programme
	NEsMP	National Estuaries Monitoring Programme
	NFEPA	National Freshwater Ecosystem Priority Areas
	NGO	Non-Governmental Organisation
	NIWIS	National Integrated Water Information System
	NIWR	National Institute of Water Research
	NLO	Nutrient Load Objective
	NPC	National Planning Commission
	NPDF	National Policy Development Framework
	NPS	Non-Point Source
	NQF	National Qualifications Framework
	NRF	National Research Foundation
	NTU	Nephelometric Turbidity Unit
	NW&S MP	National Water and Sanitation Master Plan
	NWA (36:1998)	National Water Act, 1998 (Act No. 36 of 1998), as amended
	NWMP	National Wetland Monitoring Programme
	NWQMF	National Water Quality Management Forum
	NWRS	National Water Resource Strategy
	NWSF	National Water Security Framework
O	**O&M**	Operation and Maintenance

	OECD	Organisation for Economic Cooperation and Development
	Opex	Operational expenditure
	ORASECOM	Orange Senqu River Commission
P	**PICC**	Presidential Infrastructure Coordinating Commission
	PMC	Project Management Committee
	PSC	Project Steering Committee
R	**R&D**	Research and Development
	RDI	Research, Development and Innovation
	RDM	(statutory) Resource Directed Measure
	RDP	Reconstruction and Development
	REMP	River Eco-status Monitoring Programme
	RHP	River Health Programme
	RNA	Ribonucleic acid
	RQIS	Resource Quality Information Services
	RQO	Resource Quality Objective
	RSA	Republic of South Africa
	RU	Resource Unit
	RWQO	Resource Water Quality Objective
S	**S.**	Section
	SABS	South African Bureau of Standards
	SADC	Southern African Development Community
	SALGA	South African Local Government Association
	SANBI	South African National Biodiversity Institute
	SANParks	South African National Parks
	SAPS	South African Police Service
	SAQA	South African Qualifications Authority
	SARS	South African Revenue Service
	SAWQG	South African Water Quality Guideline
	SDBIP	Service Delivery Budget and Implementation Plans
	SDC	Source Directed Control
	SDG	Sustainable Development Goal
	SEA	Strategic Environmental Assessment
	SEIAS	Socio-Economic Impact Assessment System
	SEMA	Specific Environmental Management Act
	SETA	Sector Education and Training Authorities
	SIA	Social Impact Assessment
	SMART	Specific, Measurable, Agreed-upon, Realistic and Time-based

	SO	Strategic Objective, as per the IWQM Strategy for South Africa (2017)
	spp.	Botanical shorthand for multiple species
	SRP	Soluble Reactive Phosphorus
	SSC	Strategy Steering Committee
T	**TDS**	Total Dissolved Solids
	THM	Trihalomethane
	TIA	Technology Innovation Agency
	TIN	Total Inorganic Nitrogen
	TKN	Total Kjeldahl Nitrogen
	TMDL	Total Maximum Daily Load
	TN	Total Nitrogen
	TNS	The Natural Step, as in TNS funnel
	TON	Threshold Odour Number
	TON	Total Organic Nitrogen
	TP	Total Phosphorus
	TPTC	Tripartite Permanent Technical Committee
	TSI	Trophic State Index
	TSP	Trophic Status Project
	TTT	Technical Task Team
U	**UN**	United Nations
	UNCED	United Nations Conference on Environment and Development (1992)
	UNEP	United Nations Environment Programme
	UNESCO	United Nations Educational, Scientific and Cultural Organization
	URL	Uniform Resource Locator, colloquially termed an internet web address
V	**V&V**	Validation and Verification of water use
	VIP	Ventilated improved pit latrine
W	**w**	Weight
	WA (54:1956)	Water Act, 1956 (Act No. 54 of 1956), as amended
	WAR	Water Allocation Reform
	WARMS	Water use Authorisation and Registration Management System
	WDCS	Waste Discharge Charge System
	WDS	Waste Discharge Standard
	WLO	Waste Load Objective
	WMA	Water Management Area
	WMS	Water Management System
	WQPL	Water Quality Planning Limit
	WRCS	Water Resources Classification System

WSA	Water Services Authority
WSA (108:1997)	Water Services Act, 1997 (Act No. 108 of 1997), as amended
WSDP	Water Services Development Plan
WSP	Water Services Provider
WSSD	World Summit on Sustainable Development (2002)
WTWs	Water Treatment Works
WwTWs	Wastewater Treatment Works

List of Chemical Symbols

B	**B**	boron	Is released through volcanic activity, and is present in the lithosphere, rivers, lakes and oceans. In the environment, boron combines with oxygen and other elements in compounds called borates. Boron strengthens plant cell walls. It is only required in small amounts, with excess being toxic.
C	**C**	carbon	Commonly found in the following major sinks: (1) As organic molecules in living and dead organisms in the biosphere; (2) As the gas - carbon dioxide - in the atmosphere; (3) As organic matter in soils; (4) In the lithosphere as fossil fuels and sedimentary rock deposits, such as limestone, dolomite and chalk; and (5) In the oceans as dissolved atmospheric carbon dioxide and as calcium carbonate shells in marine organisms. Both elemental and compounded carbon exists: (1) Elemental carbon exists in several forms, *e.g.,* diamonds and graphite; and (2) Compounded carbon forms the backbone of most biomolecules, including proteins, starches and cellulose. Carbon is fixed through photosynthesis, whereby carbon dioxide from the air is converted into carbohydrates which are used to store and transport energy within plants.
	Ca	calcium	Present in the lithosphere, rivers, lakes and oceans. It is the fifth most abundant element in the lithosphere. It does not occur uncombined in nature, and minerals, such as limestone (calcium carbonate); dolomite (calcium magnesium carbonate); and gypsum (calcium sulphate), are formed. Calcium regulates the transport of other nutrients into the plant; is involved in the activation of certain plant enzymes; and is involved in photosynthesis and plant structure.
	CH_4N_2O	urea	Plays a key role in the metabolism of nitrogen-containing compounds by animals and is the main nitrogen-containing substance in the urine of mammals.
	Cl	chlorine	Present in the lithosphere, rivers, lakes and oceans. It is highly reactive and does not occur uncombined in nature. The negatively charged ionic form of chlorine is chloride (Cl^-). The only way it can be found in nature is when it combines with other elements to create compounds. As compounded chloride, it is necessary for osmosis and ionic balancing; and also plays a role in photosynthesis. It is only required in small amounts.
	CO_2	carbon dioxide	A colourless gas produced by aerobic organisms and used by autotrophs during photosynthesis.

	Co	cobalt	Present in the lithosphere, rivers, lakes and oceans. Sources range from trace amounts to geological deposits that can be mined. It does not occur uncombined in nature and usually associates with other transition metals. Cobalt is beneficial to some plants; and is essential for nitrogen fixation by the nitrogen-fixing bacteria associated with legumes and other plants. It is only required in small amounts.
	Cu	copper	Present in the lithosphere, rivers, lakes and oceans. Sources range from trace amounts to geological deposits that can be mined. Elemental copper metal occurs naturally, though the greatest source of copper, by far, occurs as minerals, *e.g.,* chalcopyrite and bornite. Copper is important for photosynthesis; and is involved in many enzyme processes. It is only required in small amounts.
F	**Fe**	iron	Present in the lithosphere, rivers, lakes and oceans. It is the fourth most abundant element in the lithosphere. Sources range from trace amounts to geological deposits that can be mined. Iron is reactive and does not occur uncombined in nature. In water, iron is mainly present in two forms: either the soluble ferrous iron (Fe^{2+}) or the insoluble ferric iron (Fe^{3+}). Iron is essential for chlorophyll synthesis; and is present as an enzyme co-factor in plants.
H	**H**	hydrogen	It is the tenth most abundant element in the lithosphere and the most abundant element in the universe; present all around us. Very little hydrogen is found in elemental form due to its reactivity. Most of the terrestrial hydrogen is locked up in water molecules and organic compounds like hydrocarbons. Hydrogen is necessary for the building of sugars; and is imperative for the proton gradient to help drive the electron transport chain in photosynthesis and for respiration.
	H_2S	hydrogen sulphide	A colourless, toxic, corrosive, and flammable gas with a characteristic foul rotten egg odour that is produced from the microbial breakdown of organic matter in the absence of oxygen.
	H_2S_2	hydrogen disulphide	Decomposes readily to H_2S and elemental sulphur.
K	**K**	potassium	Present in the lithosphere, rivers, lakes and oceans. It is the seventh most abundant element in the lithosphere. Sources range from trace amounts to geological deposits that can be mined. It does not occur uncombined in nature and is found, *inter alia*, extensively as potash (KOH). Potassium has many roles in plants, including being involved in carbohydrate and protein synthesis; the regulation of internal plant moisture; acting as a catalyst and condensing agent of complex substances; acting as an accelerator of enzyme action; and contributing to photosynthesis.

M	**Mg**	magnesium	Present in the lithosphere, rivers, lakes and oceans. It is the eighth most abundant element in the lithosphere. Sources range from trace amounts to geological deposits. It does not occur uncombined in nature and combines with other elements to form minerals, such as dolomite (calcium magnesium carbonate). Magnesium is necessary for chlorophyll synthesis and photosynthesis; and is involved in many enzyme processes.
	Mn	manganese	Present in air, the lithosphere, rivers, lakes and oceans. Sources range from trace amounts to geological deposits that can be mined. It does not occur uncombined in nature. Manganese is necessary for photosynthesis and is only required in small amounts.
	Mo	molybdenum	Present in the lithosphere, rivers, lakes and oceans. Sources range from trace amounts to geological deposits that can be mined. It does not occur uncombined in nature. Molybdenum is a co-factor to enzymes, important in building amino acids; and is involved in nitrogen metabolism. It is only required in small amounts.
N	**N**	nitrogen	Is the most abundant element in the Earth's atmosphere and constitutes ±78% of the air around us. Is present in both elemental - *i.e.,* diatomic nitrogen gas (N_2) – and in compounded - *e.g.,* free ammonia (NH_3), ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-) - forms. Nitrogen plays an important role in plant biochemistry and physiology and is required in relatively large amounts, compared to micronutrients.
	NH_3	free ammonia	This un-ionized form of ammonia is a colourless, acrid-smelling toxic gas at ambient temperature and pressure. Ammonia in water comprises either free un-ionized ammonia (NH_3) and/or ammonium ions (NH_4^+).
	NH_4^+	ammonium	This ionized form of ammonia is non-toxic and occurs as salts in water. Ammonia in water comprises either free un-ionized ammonia (NH_3) and/or ammonium ions (NH_4^+).
	NO_2^-	nitrite	A pervasive intermediate in the nitrogen cycle in nature.
	NO_3^-	nitrate	Salts containing this ion are called nitrates.
O	**O**	oxygen	Is the Earth's most abundant element and constitutes ±47% of the Earth's lithosphere in the form of oxides. Is the second most abundant element in the Earth's atmosphere, after nitrogen and diatomic oxygen gas (O_2) constitutes ±21% of the air around us. Oxygen is produced during photosynthesis and is required during aerobic cellular respiration to metabolise glucose.
P	**P**	phosphorus	Present in the lithosphere, rivers, lakes and oceans. It is the eleventh most abundant element in the lithosphere. Sources range from trace amounts to geological deposits that can be mined. It is highly reactive and does not occur uncombined in

			nature. An important source of phosphorus is phosphate rock, which contains compounded apatite minerals. Phosphorus is vital to plant growth and is found in every living plant cell. It is involved in several key plant functions, including energy transfer, photosynthesis, transformation of sugars and starches, nutrient movement within the plant and transfer of genetic characteristics from one generation to the next. It is required in relatively large amounts, compared to micronutrients.
	PO_4^{3-}	orthophosphate	The form of phosphorus (P) that is water soluble, bio-available and that promotes primary production. Important component in ATP, RNA and DNA. It is required in relatively large amounts compared to micronutrients.
S	**S**	sulphur	Present in the lithosphere, particularly in the vicinity of volcanoes and hot springs, in rivers, lakes and oceans. Sources range from trace amounts to geological deposits that can be mined. Though sometimes found in uncombined form, sulphur on Earth usually occurs as sulphide and sulphate (SO_4^{2-}) minerals. Sulphide is an inorganic anion of sulphur with chemical formula S^{2-}. Sulphur is a structural component of some amino acids and vitamins; plays a role in photosynthesis; and is needed for N_2 fixation by legumes, and the conversion of nitrate into amino acids and then into protein.
	Se	selenium	Present in trace amounts in the lithosphere, rivers, lakes and oceans. In nature, selenium is rarely found in its elemental form and predominantly occurs in mineral form. Selenium is beneficial to flowering plants; stimulates plant growth in some plants; improve tolerance of oxidative stress; and increase resistance to pathogens. Selenium, however, is essential to animals and humans. It is only required in small amounts.
	Si	silicon	Present in the lithosphere, rivers, lakes and oceans. It is the second most abundant element in the lithosphere. It does not occur uncombined in nature and is usually found in silicate minerals – *i.e.,* the family of anions consisting of silicon and oxygen, such as silica (SiO_2). Silicon strengthens cell walls; and improves plant strength, health, and productivity. The frustules of diatoms contain high concentrations of silica.
	SiO_2	silicon dioxide	Also known as silica, silicic acid or silicic acid anhydride is an oxide of silicon or a silicate. Strengthens cell walls; and improves plant strength, health, and productivity.
	SO_4^{2-}	sulphate	Occurs widely in everyday life. A polyatomic ion. Sulphates are salts of sulphuric acid (H_2SO_4).

V	**Va**	vanadium	Present in the lithosphere, rivers, lakes and oceans. Sources range from trace amounts to geological deposits, typically associated with other metals, from where it is usually mined as a by-product rather than the primary mineral. In nature, vanadium is rarely found in its elemental form and predominantly occurs in mineral form. Vanadium may be required by some plants, but at very low concentrations. It may also be substituting for molybdenum.

Z	**Zn**	zinc	Present in the lithosphere. Small traces can also be present in the air, rivers, lakes and oceans. Sources range from trace amounts to geological deposits that can be mined. It does not occur uncombined in nature and is found in mineral form. Zinc participates in chlorophyll synthesis, and the activation of many enzymes. It is only required in small amounts.

Glossary of Terms and Explanations

Selected key concepts and terminology, in support of the *Eutrophication Management Strategy for South Africa*, are explained here. The interpretations provided apply throughout the document. In the main document text, where these key concepts and terminology are used for the first time in each part, a [red reference number in square brackets] has been added in superscript immediately after the particular terms. The red reference numbers there link back to the corresponding numbered alphabetically listed terms and their explanations provided in the *Glossary of Terms and Explanations* below:

[1] **Abioseston:** (or *"Tripton"*): Is the non-living particulate matter in waterbodies and includes detritus or bits of mineral matter or humus or organic remains.

[2] **Aerobic:** Presence of free oxygen, *i.e.,* O_2 (g).

[3] **Allocatable Water Quality:** The maximum worsening change in any water quality attribute away from its present value that maintains it within a pre-determined range reflecting the desired future state, typically defined by the Resource Quality Objective. If the present value is already at or outside the pre-determined range, this indicates that none is allocatable, and that (1) reduced pollution loads relating to the affected attribute(s); and/or (2) remediation of water resources, may be necessary.

[4] **Anaerobic:** Without free oxygen, *i.e.,* O_2 (g), which occurs when the uptake or disappearance of oxygen is greater than its production by photosynthesis or diffusion by physical transport from the surrounding environment. Oxygen is generally consumed by microbial respiration because of the availability of organic material.

[5] **Anoxic:** Without molecular oxygen.

[6] **Anthropogenic:** Positive or negative impacts of human activities on the environment.

[7] **Aquatic ecosystem(s):** Complex of biotic and abiotic components associated with water resources. 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.

[8] **Assimilative capacity:** Refers to the capacity of water resources to assimilate discharged or disposed waste through processes, such as dilution, dispersion, and chemical and biological degradation, without water quality changing to the extent that fitness-for-use or ecosystem health is impaired.

[9] **Atmosphere:** Is the layer or set of layers of gases surrounding the Earth that is held in place by the Earth's gravity. It composes of nitrogen (±78%), oxygen (±21%), argon (±0.9%), carbon dioxide (±0.03%) and other gases in trace amounts. Oxygen is used by most organisms for respiration; nitrogen is fixed by bacteria and lightning to produce ammonia used in the construction of nucleotides and amino acids; and carbon dioxide is used by plants, algae and cyanobacteria in photosynthesis. Additionally, the atmosphere helps to protect living organisms from genetic damage by solar ultraviolet radiation, solar wind and cosmic rays.

[10] **Autotroph:** (or *"primary producer"*) is an organism that can produce complex organic compounds from simple carbon sources, such as carbon dioxide. Autotrophs convert abiotic sources of energy, *e.g.,* light (photosynthesis) or inorganic chemical reactions (chemosynthesis), into energy stored in organic compounds which can be used by other organisms, *e.g.,* heterotrophs. Autotrophs, such as plants or algae in water, are the primary producers in a food chain, in

contrast to heterotrophs as consumers of autotrophs or other heterotrophs.

[11] **Basin:** See *"Catchment"*.

[12] **Benthic zone:** Is the ecological zone association with the stream, river or lake bottom, including the sediment surface and some sub-surface layers.

[13] **Benthos:** Is the community of organisms that live in, on, or in close association with the stream, river or lake bottom, also known as the benthic zone. The main food sources for benthic organisms are algae and organic wash-off from land. Benthos can be categorised according to–

- **Size**, *i.e., macrobenthos* (comprising the larger, visible to the naked eye, benthic organisms greater than ± 1 mm in size; *meiobenthos* (comprising tiny benthic organisms that are less than ± 1 mm but greater than ± 0.1 mm in size); or *microbenthos* (comprising benthic organisms that are less than ± 0.1 mm in size).
- **Type**, *i.e., zoobenthos* (comprising animals belonging to the benthos) or *phytobenthos* (comprising plants belonging to the benthos, *e.g.,* benthic diatoms).
- **Location**, *i.e., hyperbenthos* (living just above the sediment); *epibenthos* (living on top of the sediment); or *endobenthos* (living buried in the sediment, often in the oxygenated top layer).

[14] **Best Practicable Environmental Option:** The option that provides the most benefit or causes the least damage to the environment, at a cost acceptable to society, in the long term, as well as in the short term.

[15] **Biomass:** Renewable organic material that originates from organisms, such as plants and animals. Biomass contains stored chemical energy from the sun. Plants produce biomass through photosynthesis. Biomass can be burned directly for heat or converted to renewable liquid and gaseous fuels through various processes.

[16] **Bio-physico-chemical:** Relating to biological, physical and chemical properties or biophysical and biochemical properties.

[17] **Bioprospecting:** (or *"Biological diversity prospecting"*) Is the exploration of natural sources for small molecules, macromolecules and biochemical and genetic information that could be developed into commercially valuable products by industry for use, *inter alia* in agriculture, aquaculture, bioremediation, cosmetics, nanotechnology, or pharmaceuticals.

[18] **Bioseston:** Is the living particulate matter suspended in waterbodies, and is often regarded as plankton, although it includes nekton as well.

[19] **Blue-greens:** (or *"Blue-green algae"*; or *"Blue-green bacteria"*). See *"Cyanobacteria"*.

[20] **Carcinogen:** Is any substance, radionuclide, or radiation that promotes carcinogenesis, *i.e.,* the formation of cancer.

[21] **Catchment:** A catchment, in relation to a watercourse or watercourses or part of a watercourse, is defined as the geographical area from which any rainfall will drain into the watercourse or watercourses or part of a watercourse, through surface flow to a common point or common points. This land area from which a river or reservoir is fed is also known as a drainage region, basin or watershed.

[22] **Chemocline:** Is a type of cline, which is represented by a thin, but distinct, layer in a large body of water in which the vertical chemistry gradient changes more drastically with depth than it does in the layers above or below. In bodies of water where chemoclines occur, the cline separates the upper and lower layers, resulting in different chemical properties, *e.g.,* with respect to salinity or with respect to oxygen, in those layers.

[23] **Chlorophyll:** Is a pigment found in plants and some microorganisms (*e.g.,* cyanobacteria) that play an important role in the conversion of solar energy to chemical energy through a process known as photosynthesis.

All oxygenic photosynthetic organisms use chlorophyll-α, which contributes to the green colour of most plants and algae, but differ in accessory pigments like chlorophyll-β.

[24] **Civil society instrument(s):** Play an important role in bringing emerging water quality issues to the attention of policy makers, raising public awareness, promoting innovative ideas and approaches, and promoting transparency as well as non-corrupt activities in water management decision-making and governance.

[25] **Cline:** In water science, a cline is a comparatively thin, typically horizontal, layer within a large waterbody in which a property of the water varies greatly over a relatively short vertical distance. Such clines, and the respectively varying properties, include:

- Chemocline – chemistry;
- Halocline – salinity;
- Pycnocline – density; and
- Thermocline – temperature.

[26] **Command and control:** Is the application of direct regulatory approaches, which has traditionally been the dominant method of pollution control, and later also of water quality management. This approach affords legal authority and direction to responsible authorities over land and water users for the accomplishment of the integrated water quality management Vision, Mission and eutrophication management Goal, which are all rooted in the Bill of Rights, most notably the rights to an environment that is not harmful, as well as the availability of sufficient water for potable use.

[27] **Compliance monitoring**: Monitoring to measure, assess and report, on a regular basis, the degree to which individual water users are complying with the conditions defined in their water use authorisations (*e.g.,* in licences).

[28] **Compound(s):** In chemistry, compounds are chemical substances composed of many identical molecules composed of atoms from more than one element held together by chemical bonds, *e.g.,* H_2O (water) and $C_{12}H_{22}O_{11}$ (sugar). A molecule consisting of atoms of only one element, therefore, is not a compound.

[29] **Conservative pollutant(s):** (or *"Conservative constituents"*; or *"Conservative determinants"*) Are pollutants, which are not lost due to chemical reactions or biochemical degradation. Such pollutants may include, for example, Total Dissolved Solids (TDS) and chlorides. Conservative pollutants accumulate along the length of a waterbody in the direction of motion, so that amounts added at the most upstream point are still present at the most downstream point. Concentrations of conservative pollutants can be reduced only by dilution with water with a lower concentration.

[30] **Cost-Benefit Analysis:** Is a systematic decision support process, used to measure the benefits of a decision or taking action minus the costs associated with taking that action. A Cost-Benefit Analysis involves measurable financial metrics such as revenue earned or costs saved, as a result of the decision to pursue a project.

[31] **Cyanobacteria:** (or *"Blue-green algae"*; or *"Blue-green bacteria"*) Is a major group of photosynthetic bacteria that are single-celled, but often form colonies in the form of filaments, sheets, or spheres and are found in diverse environments (such as salt, and fresh water, soils, and on rocks). Under eutrophic conditions cyanobacteria can proliferate excessively and may produce tastes, odours and carcinogenic toxins under these noxious bloom conditions.

[32] **Deoxygenation:** is a chemical reaction involving the removal of oxygen atoms from a molecule.

[33] **Destratification:** See *"Inversion"*.

[34] **Detritus:** Is dead particulate organic material that is suspended in the water column and that accumulates in depositions on the benthic floor. Detritus typically includes the bodies, or fragments of bodies, of dead organisms and/or faecal material. Detritus typically hosts communities of microorganisms that colonize and decompose (*i.e.,* re-mineralise) it.

[35] **Diatom(s):** Are photosynthetic eukaryotic micro-algae that occur in inland waters, oceans and soils. In water resources, diatoms can occur as phytoplankton, living in the water column; or as phytobenthos, living in the

benthic zone. They are unicellular species which exist individually, or in chains or in groups. Depending on the species, their sizes can range from a few micrometres (µm) to a few hundred micrometres. Living diatoms make up a sizeable portion of the Earth's biomass and annually generate ± 20 - 50% of the oxygen produced on the planet and annually take in over 6.7 billion metric tons of silica from the waters in which they live. Diatoms are used as indicator organism to monitor past and present aquatic health conditions and are commonly used in water quality studies.

[36] **Diazotroph(s):** Are bacteria and archaea that fix atmospheric nitrogen gas into a more usable form, such as ammonia. A diazotroph is a microorganism that can grow without external sources of fixed nitrogen.

[37] **Differentiated Approach:** Acknowledges that catchments differ fundamentally-

- in an ecological sense;
- in the way they are used; and
- in the extent of such use,

the Differentiated Approach strives to ensure that catchment-specific conditions are considered in all management decisions.

[38] **Diffuse pollution:** (or *"Non-point source pollution"*) Pollution that originates from wash-off over a relatively large area. Diffuse pollution sources can be divided into source activities related to either land or water use, including failing septic tanks, agricultural and improper animal-keeping practices, and urban and rural runoff.

[39] **Dissolved oxygen:** Is the amount of oxygen dissolved in water and provides a measure of the amount of oxygen available for biochemical activity in a waterbody. It is an indicator of the quality of that water.

[40] **Drainage region:** See *"Catchment"*.

[41] **DPSIR Framework:** The Driver-Pressure-State-Impact-Response (DPSIR) framework provides a structure within which to present the indicators needed to enable feedback to policy makers on environmental quality and the resulting impact of the political and governance choices made, or to be made in the future.

[42] **Duty of care:** A legal obligation that can be considered as a formalisation of the implicit responsibilities (social contract) held by individuals towards others within society. For instance, Sections 28 of the National Environmental Management Act, 1998 (Act No. 107 of 1998) and 19 of the National Water Act, 1998 (Act No. 36 of1998) places an absolute duty of care on *"every person"* in connection with *"pollution"*.

[43] **Ecological resilience:** Is the capacity of an ecosystem to respond to a disturbance by resisting damage and recovering quickly.

[44] **Ecological water requirement:** Are the quantity and quality of water required to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource.

[45] **Economic instrument(s):** Aim to bridge the gap between private and social costs by internalising all external costs, both depletion costs (User-Pays Principle) and pollution costs (Polluter-Pays Principle). Economic instruments offer an alternative to the traditional *"command-and-control"* instruments used in direct regulation.

[46] **Ecosystem:** An interactive system that includes the organisms of a natural community, associated together with their abiotic physical, chemical, and geochemical environment.

[47] **Ecosystem services:** Are the many and varied benefits to humans provided by the natural environment and from healthy ecosystems. Ecosystem services are commonly divided into the following four categories:

- **Supporting services** (*e.g.,* primary production and nutrient cycling);
- **Provisioning services** (*e.g.,* water, food, drugs and genetic resources);
- **Regulating services** (*e.g.,* flood attenuation, herbivory, pest control and pollination); and
- **Cultural services** (*e.g.,* recreational, spiritual and cultural benefits)

[48] **Effluent:** Municipal sewage or industrial wastewater (untreated, partially treated, or fully treated) that flows out of a wastewater treatment works, septic system, pipe, etc.

[49] **Element(s):** In chemistry, an element is a pure substance consisting only of atoms that all have the same numbers of protons in their atomic nuclei, *e.g.,* P (phosphorus) or Cl (chlorine). Unlike compounds, elements cannot be broken down into simpler substances by chemical means. The number of protons in the nucleus is the defining property of a chemical element and is referred to as its atomic number. Most chemical elements occur compounded, or in combined form, in nature.

[50] **Enforcement:** The actions taken by government to achieve full implementation of environmental requirements (compliance) within the regulated community, and to correct or halt situations or activities that endanger the environment or public health.

[51] **Environment:** NEMA (107:1998) defines the environment as the surroundings within which humans exist and that are made up of—

- the land, water and atmosphere of the Earth;
- micro-organisms, and plant and animal life;
- any part or combination of the aforementioned 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.

[52] **Environmental Impact Assessment:** Is a systematic decision support process, aimed at-

- identifying, predicting and evaluating the ecological, social and economic impact(s) of development activities;
- providing information on the environmental consequences for decision making; and
- promoting environmentally sound and sustainable development through the identification of appropriate alternatives and mitigation measures.

[53] **Environmental offsetting:** Is the process of establishing and quantifying the negative effects on the environment that result from (an) activity(ies), which remain after every effort has been made to avoid and prevent, minimise and then remediate these impacts. The process then counterbalances these remaining impacts through interventions, which avoid, prevent, minimise and remediate impacts or impacted areas elsewhere, in order to achieve a net environmental gain.

[54] **Environmental Risk Assessment**: Overall process to-

- identify environmental hazards and risk factors that have the potential to cause harm (hazard identification);
- analyse the probability and extent of the risks associated with those hazards (risk analysis); and
- determine appropriate ways to mitigate the hazards or control the risks when such hazards cannot be eliminated (risk control).

[55] **Epilimnion:** (or *"Surface layer"*) Is the top-most water layer in a thermally stratified waterbody, above the thermocline. The epilimnion is generally warmer, more prone to mixing due to wind action and typically has a higher pH and higher dissolved oxygen concentration than the deeper hypolimnion. Because the epilimnion receives the most sunlight it contains the most phytoplankton. As they grow and reproduce, the phytoplankton absorbs nutrients from the water. When they die, they sink into the hypolimnion resulting in the epilimnion becoming depleted of nutrients.

[56] **Euphotic Zone:** (or *"Photic zone"*; or *"Sunlight zone"*) is the uppermost layer of a waterbody that receives sunlight, allowing phytoplankton to perform photosynthesis. It undergoes a series of physical, chemical, and biological processes that supply nutrients in the epilimnion. The photic zone is home to most of the aquatic life due to its location.

[57] **Eutrophic:** Is a state of an aquatic ecosystem rich in minerals and nutrients, very productive in terms of aquatic plant life and exhibiting increasing signs of water quality problems.

[58] **Eutrophication:** (from the Greek *"eutrophos"* meaning "*well-nourished*") Is the process of over-enrichment of waterbodies with minerals and nutrients, which (at the right temperatures, substrate availability, flow velocity and light penetration) increasingly induce primary production, *e.g.,* algal and macrophyte growth. Eutrophication can be regarded as either a natural aging process in waterbodies or an aging process that can be accelerated by anthropogenic activities.

[59] **Existing Lawful water Use:** Means the lawful use of water authorised by, or under any law, and which took place at any time during the period from 1 October 1996 to 30 September 1998, *i.e.,* the two years before the National Water Act, 1998 (Act No. 36 of 1998) came into effect.

If a water user discontinued a water use, or took steps to implement a water use, but did not begin the water use before 30 September 1998, the water use can be declared an existing lawful water use under the Act of 1998.

Certain stream flow reduction activities and controlled activities also fall under the requirements of existing lawful water use.

[60] **Facultative anaerobic bacteria:** Bacteria that can produce ATP by aerobic respiration, if oxygen is present, but can switch to fermentation, if oxygen is absent.

[61] **Flagellate(s):** Are cells or organisms possessing one or more whip-like appendages called flagella.

[62] **Freshwater:** Water that contains minimal quantities of dissolved salts (not sea water or brackish water). It originates from precipitation of atmospheric water, vapour or melting snow, reaching inland surface and groundwater resources.

[63] **Frustule:** Is the hard and porous cell wall or external layer of diatoms. The frustule is composed almost purely of silica (SiO_2), made from silicic acid, and is coated with a layer of organic substance, which is composed of several types of polysaccharides.

[64] **Geosmin:** Produced *inter alia* by several blue-green algae (cyanobacteria). Is an organic chemical compound having a distinctive earthy or musty odour. Geosmin, along with 2-methylisoborneol, accounts for the majority of biologically caused taste and odour outbreaks in drinking water. The geosmin odour detection threshold in humans is very low, ranging from 0.006 to 0.01 µg/ℓ in water.

[65] **Halocline:** Is a type of cline, specifically a subtype of chemocline, which is represented by a thin, but distinct, layer in a large body of water in which the vertical salinity gradient changes more drastically with depth than it does in the layers above or below. Because salinity (in concert with temperature) affects the density of water, it can play a role in its vertical stratification.

[66] **Heterocyst(es):** Are specialised nitrogen-fixing cells formed during nitrogen starvation by some filamentous cyanobacteria, such as *Nostoc punctiforme*, *Cylindrospermum stagnale*, and *Anabaena sphaerica*. They fix nitrogen from diatomic nitrogen gas (N_2) using the enzyme nitrogenase to provide the cells in the filament with nitrogen for biosynthesis.

[67] **Heterotroph:** Is an organism that cannot produce its own food, instead taking nutrition from other sources of organic carbon, mainly plant or animal matter. In the food chain, heterotrophs are primary, secondary and tertiary consumers, but not producers.

[68] **Hydrosphere:** Is the combined mass of water found on, under, and above the surface of the Earth. It has been estimated that there are ±1 386 million cubic kilometres of water on Earth, including water in liquid and frozen forms in groundwater, oceans, lakes and streams. Saltwater accounts for ±97.5% of this amount, whereas freshwater accounts for only ±2.5%. Of the freshwater, ±68.9% is in the form of ice and permanent snow cover in the Arctic, the Antarctic and mountain glaciers; ±30.8% is in the form of fresh groundwater; and only ±0.3% of the freshwater on Earth is in easily accessible lakes, reservoirs and river systems.

[69] **Hypertrophic:** Refers to a high degree of nutrient over-enrichment of surface water resources and excessive amounts of biological productivity that can be sustained. The fitness-for-use of such water resources for many water users, such as the ecology, irrigated agriculture, domestic water use and recreation, is significantly impaired.

[70] **Hypolimnion:** (or *"Bottom layer"*) Is the bottom-most water layer in a thermally stratified waterbody, below the thermocline. The hypolimnion is generally cooler, relatively stagnant and typically has a lower pH and lower dissolved oxygen concentration than the higher epilimnion. During nutrient-rich conditions, dying phytoplankton may sink from the epilimnion into the hypolimnion to cause, or to exacerbate, anaerobic conditions.

[71] **Hypoxia:** Lack of oxygen or deprived of adequate oxygen.

[72] **In-aquifer water quality objective(s):** Is the collective name for Resource Water Quality Objectives, Water Quality Planning Limits and the water quality components of Resource Quality Objectives that are applicable to groundwater resources, only.

[73] **In-stream water quality objective(s):** Is the collective name for Resource Water Quality Objectives, Water Quality Planning Limits and the water quality components of Resource Quality Objectives that are applicable to surface water resources, only.

[74] **In-water resource water quality objective:** Is the collective name for Resource Water Quality Objectives, Water Quality Planning Limits and the water quality components of Resource Quality Objectives that are applicable to both surface and groundwater resources.

[75] **Integrated Units of Analysis:** Are the spatial units that are defined to include significant water resources. The objective of defining Integrated Units of Analysis is to establish broad scale units for assessing the socio-economic implications of different catchment configuration scenarios and to report on the ecological conditions at a sub-catchment scale. An Integrated Unit of Analysis, thus, represents a homogenous socio-economic area which require its own specification of the Water Resource Class.

[76] **Inversion:** (or *"Destratification"*; or *"Turn-over"*) Is the process of a water column turning over from top (epilimnion) to bottom (hypolimnion). During the summer months, due to the sun's radiation, the epilimnion, or surface layer, is warming faster. The deepest layer, the hypolimnion, is the coldest, because of the sun's radiation not reaching this cold, dark layer. During late summer and autumn, the cooler air temperatures induce greater heat loss as compared to radiation heat influx, and the warm surface water gradually begins to cool down. As water cools, it becomes denser, causing it to sink, where it is gradually mixed into the lower metalimnetic layer by a combination of convection currents and wind-induced circulation of the depth-increasing epilimnetic layer. The cooler, denser, mixed epilimnetic water weakens the metalimnion and the thermocline by changing the temperature characteristics to cooler water and pushes it down to the oxygen-poor, cooler water of the hypolimnion, until the temperatures are equal, causing *"turn over"* or *"inversion"* of the layers. Inversion is more pronounced in water columns of greater depth, such as in deep lakes or dams. A sudden inversion of the water layers can cause the death of aquatic fauna, *e.g.,* fish kills, when introducing them to the oxygen poor water of the hypolimnion.

[77] **Liebig's Law of the Minimum:** States that growth is dictated not by total resources available, but by the scarcest resource (*i.e.,* limiting factor).

[78] **Life Cycle Assessment:** Is a systematic decision support process, aimed at analysing potential environmental impacts associated with products or services during their entire life cycle.

[79] **Lithosphere:** Is the solid outermost shell of the Earth and is composed of the crust and the portion of the upper mantle that behaves elastically on time scales of thousands of years or greater. The crust and upper mantle are distinguished based on chemistry and mineralogy. The lithosphere is bounded by

the atmosphere, above, and the asthenosphere (another part of the upper mantle), below.

[80] **Macrophyte(s):** Are higher plants that grow in water-saturated soil, in or near water sources, and can be emerged, submerged, or floating.

[81] **Maintenance of infrastructure:** Includes planned maintenance; repairs; refurbishment and renewal; and provisioning for replacement. Infrastructure maintenance must be included into the whole-life cycle costing of infrastructure development at the planning stage.

[82] **Management Unit(s):** (or *"Water resource Management Units"*) are geographical areas, principally defined by drainage region boundaries that are delineated by considering inherent catchment and socio-economic attributes, and for which one, or more in-water resource water quality objective(s), such as Resource Water Quality Objectives or Water Quality Planning Limits, and Waste Load Objectives, have been determined.

The Management Unit for water resource classification is the *"Integrated Unit of Analysis"* and for the determination of Resource Quality Objectives, it is the *"Resource Unit"*.

[83] **Mean annual runoff:** The average volume of water that flows in a river per year (annum), expressed as cubic meters per annum.

[84] **Mesotrophic:** Refers to a moderate degree of nutrient enrichment of surface water resources and a fair amount of biological productivity, which can occur with emerging signs of water quality impairment.

[85] **Metalimnion:** (or *"middle layer"*) Is the zone of rapid temperature change occurring between the upper epilimnion and the deeper hypolimnion in a thermally stratified waterbody. The metalimnion contains the thermocline.

[86] **Methemoglobinemia:** Or blue-baby syndrome is a disease where high nitrates interfere with blood-oxygen levels in infants. Due to the very high solubility of nitrates, and because soils are highly unable to retain anions, nitrates can enter groundwater. Elevated nitrate in groundwater is a concern for borehole drinking water use because of methemoglobinemia.

[87] **Mineral(s):** Are building blocks of rocks and are typically solid, inorganic, have crystalline structures and are naturally formed by geological processes, *e.g.,* sulphide minerals, such as pyrite or fool's gold. Mineral research is called mineralogy.

[88] **Mineralisation:** In biology, mineralisation is the process by which chemicals present in organic matter are decomposed or oxidized into easily available forms to plants to contribute to nutrient cycling.

[89] **Molecule:** In chemistry, a molecule is an electrically neutral group of two or more atoms held together by chemical bonds, *e.g.,* N_2 (nitrogen) and O_3 (ozone). Molecules are distinguished from ions by their lack of electrical charge, *e.g.,* PO_4^{3-} (orthophosphate).

[90] **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.

[91] **Mutagen:** Is a physical or chemical agent that changes the genetic material (*i.e.,* RNA or DNA) of an organism, increasing the frequency of mutations above the natural background level. As many mutations can cause cancer, mutagens are often also carcinogens. All mutagens have characteristic mutational signatures with some chemicals becoming mutagenic through cellular processes.

[92] **Nekton:** (or *"Nekton"*) Refers to the actively swimming aquatic organisms in waterbodies. The term is used to differentiate between active swimmers and passive organisms, such as plankton, which are carried along by the water current.

[93] **Nitrogen**: (or *"N"*) Is a colourless and odourless element found in the soil and atmosphere in gas and water. In fact, nitrogen is the most abundant element in the Earth's atmosphere – approximately 78% of the

atmosphere is nitrogen. Nitrogen supports growth and reproduction.

[94] **Non-conservative pollutant(s):** (or *"Non-conservative constituents"*; or *"Non-conservative determinants"*) Are pollutants that decay with time due to mechanisms, such as chemical reactions; bacterial degradation; radio-active decay; or settling of the particulates out of the water column. Many pollutants exhibit non-conservative behaviour, including nutrients, oxidisable organic matter, volatile chemicals and bacteria. The amount of a non-conservative pollutant decreases with time and/or over distance from the point of input.

[95] **Non-point source pollution:** See *"Diffuse pollution"*.

[96] **Noxious:** Harmful, poisonous, or very unpleasant.

[97] **Nutrient:** Is a substance used by an organism to survive, grow, and reproduce. In aquatic biology, the most important nutrients are nitrogen, phosphorus, silica and carbon.

[98] **Nutrient cycle:** (or *"Ecological recycling"*) is the movement and exchange of organic and inorganic matter back into biomass production. Energy flow is a unidirectional and non-cyclic pathway, whereas the movement of nutrients is cyclic.

[99] **Nutrient depletion:** Reduction of essential nutrients through uptake and removal of plant and animal residues. Nutrients are usually the first link in the food chain, thus a loss of nutrients in a habitat will affect nutrient cycling and eventually the entire food chain.

[100] **Nutrient enrichment:** A form of water pollution, which refers to contamination by excessive nutrient inputs. It is the primary cause of eutrophication of surface waters, in which excess nutrients, usually nitrogen or phosphorus, stimulates growth of algae and other aquatic plants.

[101] **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.

[102] **Nutrient-loading:** Refers to the input of nutrients into the aquatic ecosystem from numerous anthropogenic and non-anthropogenic sources.

[103] **Oligotrophic:** Refers to surface water resources low in nutrients and low levels of biological productivity that can be sustained.

[104] **Oligotrophication:** The process of nutrient depletion, or reduction in rates of nutrient cycling in aquatic ecosystems. It often arises because of acidification, typically the result of pollution and most notably associated with air pollution and acid precipitation.

[105] **Participatory management:** Is the practice of empowering members of a group, such as community members, to participate in decision-making. It is used as an alternative, or to support traditional vertical management approaches, which has shown to become less effective when participants grow less interested in authorities' expectations, due to a lack of recognition of participant's efforts or opinions.

[106] **Periphyton:** Is a complex mixture of algae, cyanobacteria, heterotrophic microbes, and detritus that is attached to submerged surfaces in most aquatic ecosystems. Periphyton serves as an important food source for invertebrates, tadpoles, and some fish. It can also absorb contaminants, removing them from the water column and limiting their movement through the environment and is also an indicator of water quality.

[107] **Phosphorus**: (or *"P"*) Is a chemical element that is highly reactive and, consequently, is never found as a free element on Earth. Phosphorus is essential for life. Phosphates (compounds containing the phosphate ion PO_4^{3-}) are found in genetic material, *i.e.,* deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), the energy-carrying molecule adenosine triphosphate (ATP) that fuels cellular processes, and phospholipids that constitute a key component of cell membranes.

[108] **Photic zone:** See *"Euphotic zone"*.

[109] **Physico-chemical:** Relates to physics and chemistry, or to physical chemistry.

[110] **Phytoplankton:** Are the autotrophic (self-feeding) component of the plankton community found floating in freshwater and marine ecosystems. Most phytoplankton are too small to be individually seen with the unaided eye. However, when present in high enough numbers, some varieties may be noticeable as coloured patches on water surfaces due to the presence of chlorophyll within their cells. About 1% of the global biomass consists of phytoplankton and they are an important source of atmospheric oxygen. Diatoms and cyanobacteria are examples of phytoplankton.

[111] **Plankton**: Are the diverse collection of small organisms drifting in water, which are unable to propel themselves against a current. Plankton can be divided into the following broad functional groups:

- Phytoplankton (autotrophic algae);
- Zooplankton (protozoans or metazoans);
- Mycoplankton (fungi);
- Bacterioplankton (bacteria and archaea); and
- Virioplankton (viruses).

[112] **Point source pollution:** Pollutant loads discharged at a specific location by means of pipes, outfalls, or conveyance channels *inter alia* delivering wastewater from municipal and industrial Wastewater Treatment Works. Point sources can also include pollutant loads contributed by tributary streams to main-stem streams or rivers.

[113] **Polluter-Pays Principle:** The principle that advocates for payment, by those responsible or potentially responsible for damage to the environment and/or human health, of repair costs and costs of preventive measures to avoid and prevent and/or minimise further pollution and environmental damage.

[114] **Precautionary Principle:** An approach that exercises caution when uncertainties exist, generally assuming a worst-case scenario.

[115] **Primary production:** In ecology, primary production is the synthesis of organic compounds from atmospheric or aqueous carbon dioxide. It principally occurs through the process of photosynthesis, which uses light as its source of energy, but can also occur through chemosynthesis, which uses the oxidation or reduction of inorganic chemical compounds as its source of energy. Almost all life on Earth relies directly or indirectly on primary production. The organisms responsible for primary production are known as primary producers or autotrophs and form the base of the food chain.

[116] **Primary productivity:** The rate at which light energy is incorporated into plant cells.

[117] **Pycnocline:** Is a cline, which is represented by a thin, but distinct, layer in a large body of water in which the vertical density gradient changes more drastically with depth than it does in the layers above or below. Below the mixed layer, a stable density gradient (or pycnocline) separates the upper and lower water, hindering vertical transport.

[118] **Quinary drainage region(s):** Are altitudinally based fifth level sub-quaternary drainage regions that are utilised as planning units for operational decision making and general coordination purposes; hydrological modelling; and integrated water resource management.

[119] **Receiving Water Quality Objectives Approach:** This approach recognises that many receiving water resources have a certain dilution capacity that can accommodate both point and diffuse sources of pollution without serious detriment to the water quality requirements of the recognised water users. Appropriate source controls must be instituted upstream in order to ensure compliance to the downstream Water Resource Class (and RQOs/ Reserves), as may be supported by Resource Water Quality Objectives and/or Water Quality Planning Limits.

[120] **Recycle:** Utilization of treated or untreated wastewater for the same process that generated it, *i.e.,* it does not involve a change of user. For instance, recycling the effluents in a paper and pulp mill.

[121] **Remediation:** Means correcting to improve, vs. ***"Amelioration"*** that means making better to improve.

In environmental management, *"remediation"* addresses legacy sources of pollution, or affected ecological infrastructure. As such, ***"reclamation"*** or ***"rehabilitation"*** involves the removal of contaminants from surface water, groundwater, soil, sediment, etc. , whereas ***"reconstruction"*** or ***"restoration"*** involves returning ecological infrastructure to their original or near-original conditions.

[122] **Reserve:** Means the quantity and quality of water required to satisfy basic human needs and the aquatic ecosystem.

[123] **Resource:** In water resource management, *"resource"* refers to *"water resource"*.

[124] **Resource quality:** Means the quality of all the aspects of a water resource, including–

- the quantity, pattern, timing, water level and assurance of instream flow;
- the water quality, including the physical, chemical and biological characteristics of the water;
- the character and condition of the instream and riparian habitat; and
- the characteristics, condition and distribution of the aquatic biota;

[125] **Resource Quality Objective(s):** May relate to–

- the Reserve;
- the instream flow;
- the water level;
- the presence and concentration of particular substances in the water;
- the characteristics and quality of the water resource and the instream and riparian habitat;
- the characteristics and distribution of aquatic biota;
- the regulation or prohibition of instream or land-based activities which may affect the quantity of water in or quality of the water resource; and
- any other characteristic, of the water resource in question, if so declared.

Resource Quality Objectives provide a balance between the need to use and develop water resources, and the need to protect them.

Resource Quality Objectives are gazetted.

[126] **Resource Unit:** Is the Management Unit of assessment for the Resource Quality Objective and encompasses a stretch of a river that is sufficiently ecologically distinct to warrant its own specification of Ecological Water Requirement.

[127] **Resource Water Quality Objective(s):** Are the water quality component of the Resource Quality Objective. Are numeric and/or descriptive objectives, which address the physical, chemical and/or microbiological properties of waterbodies that should be met in receiving water resources to ensure that the water quality requirements of the recognised water users and the aquatic ecosystem are sufficiently protected.

Resource Water Quality Objectives are not gazetted, *per se*.

[128] **Respiration:** In physiology, respiration constitutes the movement of oxygen from the outside environment to the cells within tissues, and the transport of carbon dioxide in the opposite direction.

[129] **Reuse:** Utilization of treated or untreated wastewater for a process other than the one that generated it, *i.e.,* it involves a change of user. For instance, the re-use of municipal wastewater for agricultural irrigation. Water re-use can be direct or indirect, intentional or unintentional, planned or unplanned, local, regional or national in terms of location, scale and significance, involve various kinds of treatment (or not) and be used for a variety of purposes.

[130] **Root nodules:** Are found on the roots of plants that form a symbiosis with nitrogen-fixing bacteria. Under nitrogen-limiting conditions, capable plants form a symbiotic relationship with a host-specific strain of bacteria known as rhizobia.

[131] **Runoff:** Runoff is the flow of water occurring on the ground surface when excess rainwater, stormwater, meltwater, or other sources, can

no longer sufficiently rapidly infiltrate in the soil. Surface runoff replenishes groundwater and surface water resources as it percolates through soil profiles or moves into streams and rivers.

[132] **Secchi disk depth:** A 20 cm disk, with alternating black and white quadrants, is lowered into the water of a river or dam until the observer can no longer see it. The depth of disappearance is called the Secchi depth. Secchi disk depth is a measure of the clarity, transparency or turbidity of water.

[133] **Self-regulation:** An organization regulating itself without intervention from external bodies.

[134] **Seston:** Are the organisms (bioseston) and non-living matter (abioseston) swimming or floating in a waterbody.

[135] **Social Impact Assessment:** Is a systematic decision support process of research, planning and management of social change or consequences (positive and negative, intended and unintended) arising from policies, plans, developments and projects.

[136] **Source:** In water resource management, *"source"* refers to the source of an impact, usually on a water resource. The relationship between *"Source"* and *"Resource"* is similar to the relationships between *"Cause"* and *"Effect"* or *"Aspect"* and *"Impact"*, as per the ISO 14001 definitions. The *"Resource"* or the *"water resource"* is part of the receiving environment.

[137] **Standard(s):** See *"Waste Discharge Standard"*.

[138] **Strategic Environmental Assessment:** Is a systematic decision support process, aimed at ensuring that sustainability aspects are considered in policy-strategy, plan and program making. The focus is deliberately wide because many of the pressures are as a result of custom, tradition, and institutional factors.

[139] **Stratification:** Occurs when water with different properties, *viz.* salinity (halocline); oxygenation (chemocline); temperature (thermocline); and density (pycnocline), forms layers that can act as barriers to water mixing. The terms in brackets refer to the transition layers or boundaries that exist in water with respect to the different properties.

[140] **Subsidiarity:** The principle of subsidiarity requires that socio-political issues be dealt with at the most immediate or local level, consistent with its resolution.

[141] **Systems thinking:** Is a way of making sense of the complexity of the world by looking at it in terms of wholes and relationships rather than by splitting it down into its parts. Systems thinking has been used to explore and develop effective action in complex contexts to enable systems change.

[142] **Thermocline:** Is a cline, which is represented by a thin, but distinct, layer in a large body of water in which temperature changes more drastically with depth than it does in the layers above or below. The thermocline divides the upper generally warmer and mixed layer (epilimnion) from the deeper cooler and more stagnant layer (hypolimnion) and occurs in the metalimnion.

[143] **Total Maximum Daily Load**: (or *"Pollutant load allocation"*) Is the total maximum daily load 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.

[144] **Sunlight zone:** See *"Euphotic zone"*.

[145] **Trophic status:** Refers to the degree of nutrient enrichment of surface water resources and the associated amount of primary productivity that can be sustained.

[146] **Turn-over:** See *"Inversion"*.

[147] **User-Pays Principle:** Variation of the Polluter-Pays Principle that calls upon the user of a natural resource to bear the cost of running down natural capital.

[148] **Vascular plant(s):** (or *"Tracheophyta"*) form a large group of land plants with lignified tissues (the xylem) for transporting water and minerals throughout the plant and specialized

non-lignified tissue (the phloem) to transport products of photosynthesis.

[149] **Waste Discharge Standard(s):** Are rules, criteria or limits that are established to regulate the unnatural altering of the water quality of water resources by wastewater that needs to be discharged; and ensure that such discharges are compatible with receiving water quality requirements.

[150] **Waste Load Objective(s):** Are objectives relating to incremental reduction; maintenance; or under special circumstances, incremental increase in waste loads, calculated to give effect to relevant in-water resource water quality objectives. Waste Load Objectives refer to the water resource Management Unit as a whole and not to specific water users, though they do consider technical, economic and administrative realities.

[151] **Wastewater:** Any water used from domestic, industrial, commercial or agricultural activities, surface runoff or stormwater, which may contain physical, chemical and biological pollutants.

[152] **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.

[153] **Watercourse:** Means –

- a river or spring;
- a natural channel in which water flows regularly or intermittently; and
- a wetland, lake or dam into which, or from which, water flows;
- A reference to a watercourse includes, where relevant, its bed and banks.

[154] **Water Management Institution:** Means a Catchment Management Agency, a Water User Association, a Body Responsible for International Water Management or any person (*i.e.,* a natural person, a juristic person, an unincorporated body, an association, an organ of state and the Minister of Water and Sanitation) who fulfils the functions of a Water Management Institution, in terms of the National Water Act, 1998 (Act No. 36 of 1998);

[155] **Water pollution:** Means the direct or indirect alteration of the physical, chemical or biological properties of water resource so as to make it less fit for any beneficial purpose for which it may reasonably be expected to be used; or harmful or potentially harmful to:

- the welfare, health or safety of human beings:
- any aquatic or non-aquatic organisms;
- the resource quality; or
- property.

[156] **Water quality:** The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial water use.

[157] **Water Quality Planning Limit(s):** Are Resource Water Quality Objectives utilised for water quality planning purposes.

[158] **Water resource:** Includes a watercourse, surface water, estuary, or an aquifer, but excludes coastal marine waters.

[159] **Water Services Institution:** Means a Water Services Authority, a Water Services Provider or a Water Board established under the Water Services Act, 1997 (Act No. 108 of 1997).

The need for Water Services Committees has fallen away with the promulgation of the Municipal Structures Act, 1998 (Act No. 117 of 1998) that provides for the establishment of wall-to-wall municipalities.

Water Services Intermediaries are not regarded as Water Services Institutions, but are entities that are defined in the Water Services Act, 1997 (Act No. 108 of 1997).

[160] **Water user group(s):** (or *"Water user sectors"*) There are five recognised broad water user groups, some with sub-groups, namely the-

- **Agricultural water user group:**
  - *Irrigation* according to soil and crop type;
  - *Stock water*ing; and
  - *Aquaculture*.
- **Domestic water user group:**
  - Drinking water, and water used for washing and cleaning, gardening, etc.

- **Industrial water user group:**
  - *Category 1* – Strictest requirement, *e.g.,* evaporative cooling (high rate of recycling);
  - *Category 2* – *E.g.,* water heating;
  - *Category 3* – *E.g.,* firefighting; and
  - *Category 4* – Water of more or less any quality, *e.g.,* dust suppression.
- **Recreational water user group:**
  - *No-contact recreation*, *e.g.,* fishing;
  - *Intermediate contact recreation*, *e.g.,* boating, water skiing and traditional or religious ceremonies; and
  - *Full contact recreation*, *e.g.,* swimming.
- **Aquatic ecosystem:**
  - Although not a water user, *per se*, the aquatic ecosystem's instream and riparian habitat and biota water quality requirements (the Reserve, where available) are being co-considered with the water quality requirements of the other water user groups in water quality management.

[161] **Watershed:** See *"Catchment"*.

[162] **Zooplankton:** Are the heterotrophic (other-feeding) component of the plankton community in freshwater and marine ecosystems and consists of small protozoans (single-celled eukaryotes) and metazoans (multicellular eukaryotic organisms). Zooplankton are generally larger than phytoplankton, mostly still microscopic, but some are a few millimetres long and can be seen with the naked eye.

THE SOUTH AFRICAN CONTEXT

Part 1

PART 1: THE SOUTH AFRICAN CONTEXT

PHOTO 1: ***"SOME FOR ALL FOR EVER!"*** © J.J. VAN WYK

CHAPTER 1: THE EUTROPHICATION CHALLENGE

BOX 1: ***"What is eutrophication?"***

Eutrophication is the process of nutrient enrichment of waters which results in the stimulation of an array of symptomatic changes, amongst which increased production of algae and aquatic macrophytes, deterioration of water quality and other symptomatic changes found to be undesirable and to interfere with water users [OECD, 1982].

This document will focus on ways to control eutrophication that is caused by human activities – also known as *"anthropogenic eutrophication"*.

1.1 Key challenges associated with eutrophication

Anthropogenic[6] nutrient enrichment[100] of water resources[158] is a global water resource problem [Rast & Thornton, 1996]. It is most evident in highly populated and developed areas where: industrial effluent[48]; water-borne sewage systems; wash-off from built-up areas; fossil fuel combustion; atmospheric fall-out; and agricultural practices contribute to elevated loads of nutrients[97] entering receiving water resources. Elevated nutrient-loading promotes excessive primary production[115] in natural systems, causing a wide array of biological diversity [Cook, et al., 2018] and water quality problems [Dunst, et al., 1974]. South Africa itself has some of the most highly enriched surface waters in the world [Ashton, et al., 1985; Van Ginkel, et al., 2000b]. A contemporary analysis of eutrophication[58] in South Africa revealed that some 75% of the raw water stored in the major national impoundments was either eutrophic[57] or hypertrophic[69] [Harding, 2015]. Read together with the fact that the National Water Resource Strategy (NWRS) ranks eutrophication as the highest amongst thirteen tiers of water quality concern, that include salination and Acid Mine Drainage (AMD) [DWS, 2021], this is a most damning finding for a semi-arid country in which impounded water largely underpins the quality of socio-ecological and economic existence.

Eutrophication challenges in South Africa are exacerbated by insufficient wastewater infrastructure maintenance[81] and investment; deteriorating ecological infrastructure; recurrent droughts, driven by climatic variation, and an inescapable need for water resource development; inequities in access to safe sanitation, against the backdrop of a growing population; water use regulation that is not consistently and adequately protecting South Africa's water resources against eutrophication; and a lack of skilled water scientists and engineers. Poor water quality[156], including eutrophication, is already having significant impacts on economic growth and on the well-being of South Africans [DWS, 2017b].

1.1.1 *Insufficient wastewater infrastructure maintenance*

One of the most often quoted opening lines on water issues in South Africa typically reads *"… South Africa is a water scarce (or semi-arid) country with severely limited water resources …"*. What is not so often mentioned is that wastewater return-flows comprise a major component of the country's water budget and that discharges of water containing waste are required to be returned to surface water resources for indirect reused further downstream [Harding, 2017].

The importance of well-functioning municipal wastewater infrastructure[1] is embedded within the fact that it acts as the last barriers and final interface between untreated urban wastewater[151] and healthy aquatic ecosystems[7]; other receiving water users[160] that optimally contribute towards economic growth; and the health of the country's population. Whereas poor wastewater handling is known to be a lead cause of nutrient over-enrichment, this cause of eutrophication is also intertwined with other water quality challenges, such as microbial pollution and concomitant health risks; elevated Chemical Oxygen Demand (COD); and others that affect wastewater reuse[129] and recycling[120] strategies. It was found that up to 70%, and sometimes even more, of the water abstracted by cities, returns as polluted effluent [SA Commission of Enquiry into Water Matters, 1970]. Municipal urban wastewater return-flow profiles include residential, commercial, business and industrial users; as well as schools, hospitals, sports and recreation facilities, parks and government institutions. This implies that poor urban wastewater handling affects society at multiple levels.

South Africa possesses an extensive network of collection and sewer network systems, pumping stations, and WwTWs. These systems, must collectively, ensure that the quality of waterborne urban wastewater complies with authorised levels prior to it being discharged and/or reused or recycled. However, approximately 56% of the over 1 150 municipal WwTWs in the country are in a poor or critical condition and in need of urgent rehabilitation [DWS, 2018b, p. 5.1]. Additionally, the facilities previously provided to some households have become inadequate due to various factors (including poor facilities operation and infrastructure operating above its design capacity (**FIGURE 1)**; vandalism, ageing infrastructure and insufficient maintenance (**FIGURE 2**); poorly constructed and operated on-site sanitation systems; and ventilated improved pit latrine (VIP) pits and septic tanks not being emptied regularly). Compliance with the Green Drop requirements (assessed in 2021 as part of the 2022 Green Drop Assessment [2]) was generally very poor – with 828 WwTWs out of a total of 850 WwTWs being unable to achieve Green Drop Certification [DWS, 2022].

South Africa is one of the most unequal countries in the world, with extremely high levels of poverty. Sixty-three percent of households earn less than R 38 000 per year (*i.e.* being at indigent level) resulting in high levels of grant dependency with related impacts on affordability and services viability. Some 77% of rural households are indigent and are not required to pay for basic municipal services. The percentage of individuals that benefited from social grants in 2003 consistently increased from 12.7% to 29.7% in 2016 [DWS, 2018b], placing an ever-increasing burden on already limited government financial resources to finance operation and maintenance of municipal WwTWs. Today, effective administrative and management practices are also hampered by systemic corruption that is associated with many municipalities in South Africa [Muller & Erasmus, 2020].

This resulted in a lack of proper operation and maintenance of *"regulated"* WwTWs, as well as *"unregulated"* sanitation services (such as on-site sanitation systems) in most municipalities. The discharge or leaking of sub-standard return-flows or untreated sewage to the environment is a frequent occurrence that significantly contributes towards nutrient-loading of water resources – hence the prevalence of eutrophication. Consistent operation and maintenance of wastewater infrastructure, coupled with good

[1] Municipal infrastructure includes wastewater network and pump systems, and treatment works (WwTWs) [152].

[2] The Green Drop Certification Programme has been relaunched by the Department of Water and Sanitation with a full Green Drop audit conducted in 2021/22.

practices, is essential for enhancing principles of health, dignity and protection of water resources, towards an improved quality of life for all in South Africa.

FIGURE 1: Streams of poorly treated and untreated sewage and industrial wastewater, exacerbating the effects of anthropogenic eutrophication, have become an all too familiar face in many parts of the country. Photos: © P. Venter.

FIGURE 2: Vandalism, ageing infrastructure and insufficient maintenance of sewage infrastructure cause water pollution, which contributes to eutrophic conditions in receiving water resources. Main photo: © P. Venter; Insert photo: © J.J. van Wyk.

1.1.2 Deteriorating ecological infrastructure

The basic hydrological unit for water resource quality[124] management is the catchment[21] and it is necessary to recognise the unity of the water cycle and the interdependence of its elements, where evaporation, clouds and precipitation are linked to groundwater, rivers, lakes, wetlands and the sea [DWAF, 1997]. Every catchment relies heavily on extensive ecological infrastructure to maintain healthy functioning aquatic ecosystems and to provide much needed services, or *"nature-based solutions"*, to people. Ecological infrastructure includes, for instance, mountain catchment areas, streams, rivers and sub-surface water movement, floodplains, lakes, wetlands, estuaries, coastal dunes, and the marine environment, as well as beds and banks of water resources, and nodes and corridors of natural habitat, which together form a network of interconnected structural elements in the landscape [SANBI, 2014]. The ecological infrastructure in catchments renders valuable services, such as freshwater for domestic, industrial, agricultural and recreational use; ecotourism; soil formation; medicine and food (including fish, wild foods and others) provisioning; hydropower generation; climate variability regulation; flood and drought risk reduction; purification of air; crop pollination; pest and disease control; waste decomposition and detoxification; and water quality improvement functions (including nutrient cycling and dispersal); and much more! It is the nature-based equivalent of built or hard infrastructure, and is just as important for providing services, ensuring water security and underpinning socio-economic development. Because the services derived from ecological infrastructure are effectively *"free services"*, we tend to take their benefits for granted. Indeed, few, if any, authorities or utilities list catchments as assets anywhere on their books, and landowners are not rewarded for good management practices that result in downstream user benefits [WRC, 2014].

A healthy aquatic ecosystem is one that is intact in its physical, chemical and biological components, and their interrelationships, such that it is resilient to withstand changes and stressors. It is a system that is not experiencing: abnormal growth or decline of native species; persistence of elevated concentrations of contaminants (such as excessive orthophosphate, as shown in **FIGURE 3** [3]); or drastic anthropogenic changes to its landscape or ecological processes [Baron & Poff, 2004].

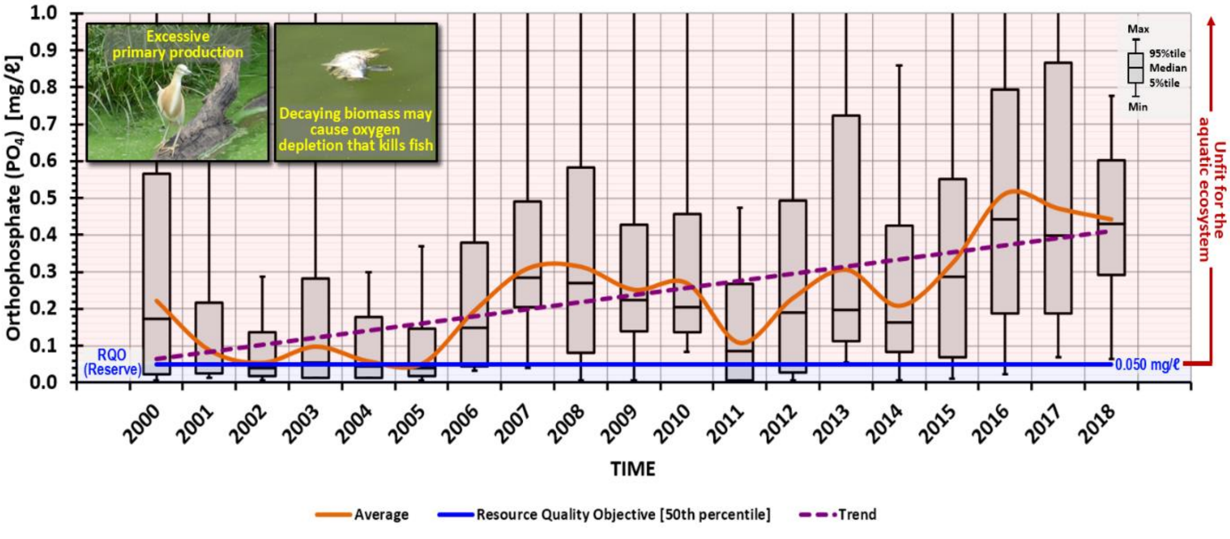

FIGURE 3: The aquatic ecology is the most sensitive water user with respect to orthophosphate. The graph shows that the Reserve, determined to protect the Hartbeespoort Dam ecology, is being exceeded frequently. Insert photos: (Left) © P. Venter; (Right) © J.J. van Wyk.

[3] The Reserve, as per IUA 3/ RU 3.1/ EWR 3 in Drainage Region A21J [GN R.1388, 2017], that has application to the Hartbeespoort Dam was used. An average of 15 samples per month, taken close to the dam wall, were used for the statistical analysis. The samples taken at depths ranging from the surface up to 5 metres were all treated equally, and were regarded as representative of the water quality of the dam, *i.e.* the assumption is that the dam acts a completely mixed body of water for the purpose of representing the data on the graph.

Unfortunately, much needed socio-economic development and growth are often synonymous with adverse impacts on ecosystem health and concomitant ecological infrastructure. Human-induced impacts accelerate the effects of nutrient-loading and eutrophication. **FIGURE 4** [4] shows increasing trends for both nitrogen[93] loading and primary production across six large South African dams. The reasons for the slight improvement in phosphorus loading is unclear, although the possibility that this may be caused linked to the introduction of phosphate free detergents a few years ago in South Africa, cannot be discounted [DWS, 2015b]. An average annual phosphorus[107] load of ~600 tons and a nitrogen load of ~2 000 tons across the six large dams are evident.

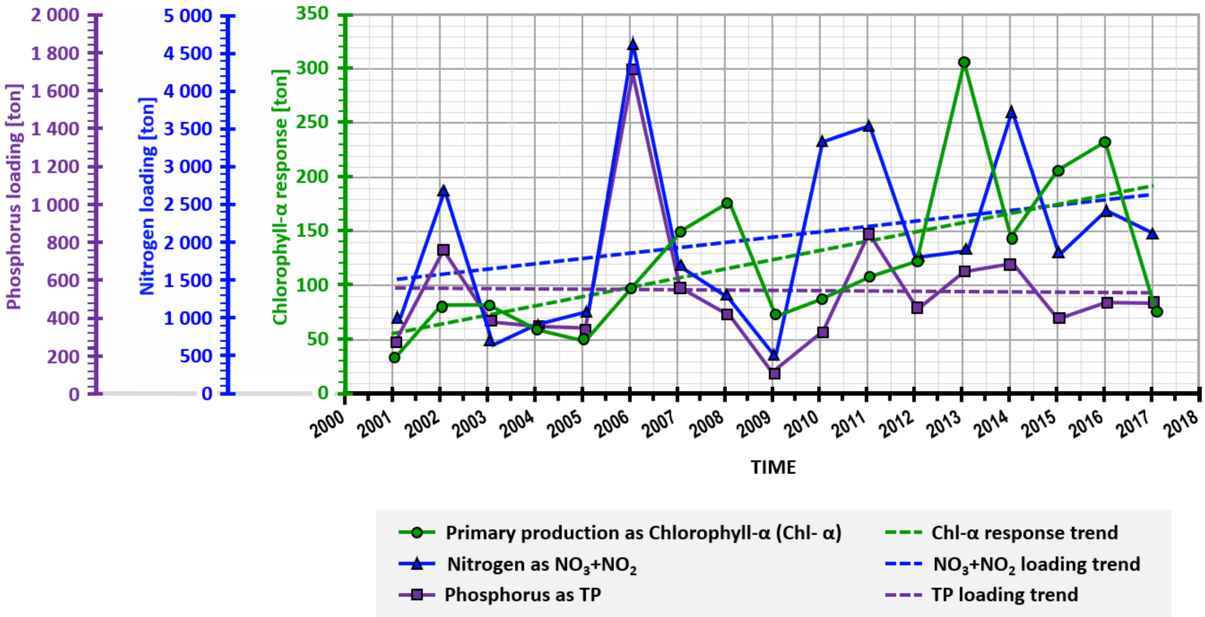

FIGURE 4: Annual phosphorus and nitrogen loading of, and primary production in six large South African dams.

Eutrophication, as one of the importunate environmental hazards of aquatic ecosystems, causes pronounced cascading deterioration of water quality and poses risks to biotic components, which, amongst others, include [Schmutz & Sendzimir, 2018; Clark, et al., 2017; Padedda, et al., 2017; Chamier, et al., 2012; Baron & Poff, 2004; Walmsley, 2000]:

- Increased occurrences of floating and rooted aquatic macrophytes[80];
- Native plant species loss and replacement with alien plant species, often also affecting resource water quality through reduced dilution capacity, resulting from increased evapotranspiration; altered nutrient cycling, especially due to nitrogen fixers such as *Acacia* spp.; and increased occurrences of soil erosion, associated with the increased fire hazards;
- Increased occurrences and intensity of nuisance algal blooms;
- Increasing dominance of cyanobacteria[31] and the occurrence of toxic cyanobacteria;
- The abundance of cyanobacteria impacts greatly on the aesthetic quality and general consumer acceptability of drinking water due to the presence of major organic pollutants, such as Geosmin and 2-methylisoborneol (2-MIB), that are responsible for undesirable taste and odour in water. Geosmin

[4] Loads were calculated for the Hartbeespoort, Roodeplaat, Bloemhof, Vaal, Vanderkloof and Sterkfontein Dams. The first three of these dams, compared to the latter three, are known to experience elevated trophic conditions. For the load calculations, it was assumed that the epilimnions of the six dams each acts as a completely mixed system. Averaged surface water quality samples taken at the dam walls and daily dam total outflow volumes were used to calculate monthly load estimates.

and 2-MIB are some of the most difficult compounds to remove during water treatment. They increase filter clogging, the requirements for dosing activated carbon and greatly affect water treatment costs;

- Undesirable aesthetic conditions, include discolouration, increased turbidity and loss of clarity, foaming, presence of odours, etc.;
- Severe shading and light attenuation, caused by blooms of both macro-algae and phytoplankton[110]; and the presence of debris hinder the photosynthetic processes in benthic[12] plants, which leads to benthic habitat stress and destruction;
- Loss of benthic diversity affects and lead to stressed bottom-feeding fish and other animals;
- Increased occurrences of deoxygenation[32] in reservoir bottom waters leads to elevated levels of hydrogen sulphide, heavy metals and nutrients;
- The decomposition of organic matter leads to an over-supply of CO_2, which, in turn, also enhances water acidification;
- Excessive algal blooms are harmful to, and lead to injury of aquatic animals, such as the clogging of fish's gills, poisoning by toxins secretion, and localized anoxia[5] that effects subsistence and sports fishing;
- Increased fish and invertebrate mortality;
- Changes of ecological community structure and loss of biological diversity; and
- Mortality of domestic and wild animals, drinking hypertrophic[69] waters that contains toxins.

The White Paper on a National Water Policy for South Africa (1997) states: *"The sustainable use of water resources means that, even where the immediate demands for development are very high, society must find different development approaches which make sure that the use of water resources does not destroy their ability to recover"* [DWAF, 1997]. Protecting our ecological infrastructure is not optional but obligatory!

1.1.3 Recurrent droughts (driven by climatic variation) and an inescapable need for water resource development

Large parts of South Africa suffer from relatively low rainfall and water resources are highly developed, especially surface water systems, through a myriad of large dams around the country [DWS, 2018b, p. 3.9]. Dams are a *"necessary evil"* that, together with many other water supply interventions, must assist to ensure continued water security in the country [Venter, 1971, p. 29; DWA, 1986, p. 6.45]. However, the damming of surface water resources greatly modifies the ecological functioning of river systems. In particular – dams sequester nutrient elements and, hence, reduce downstream transfer of nutrients to floodplains, wetlands, lakes and the coastal marine environment. Additionally, impoundment influence regional nutrient limitation[101] patterns, food web dynamics and trophic conditions, often resulting in the presence of hypertrophic conditions in reservoirs [Maavara, et al., 2015].

The Hartbeespoort Dam was constructed in 1923, about 35 kilometres north-west of Johannesburg and 20 kilometres west of Pretoria, and first overflowed in March 1925 [De Beer, 1975, p. 405]. Originally constructed for irrigation purposes, and today, also utilised for domestic, recreational and industrial purposes, the dam has been experiencing nuisance algae and floating water plant problems since the late 1950s [Pers. coms. Silberbauer, 2022]. Impacts emanating from the upstream urban zones are increasingly affecting the resource quality of the Hartbeespoort Dam. **FIGURE 5** attests to this by showing how the trophic conditions are affecting the fitness-for-use of the Hartbeespoort Dam for recreational purposes; also affecting the regional economy and property values in the vicinity of the Dam.

Drought conditions in South Africa, driven by climate variation are expected to have a major impact on South Africa, with resulting consequences for ecosystems[46], people and the economy. Water is the primary medium through which the impact of climate change is going to be experienced [DWS, 2013]. Climate change is expected to result in changing rainfall patterns; changing storm intensities and the extremes of floods and droughts; higher solar radiation intensities; higher ambient air temperatures; increasing evaporation; changes in soil moisture and runoff[131]; higher demands for water in some areas and changes in water availability; changing water quality conditions (including the water temperature of aquatic systems); and increasing climate variability [DWS, 2015a]. Climate change is expected to amplify deteriorating trophic conditions in water resources by changing the internal and external nutrient-loadings[102], as an impact of ambient temperature rise; changing precipitation patterns; altered solar radiation intensity; and altered wind speeds [Nazari-Sharabian, et al., 2018].

Warmer water temperatures, resulting from heat exchange between a warmer ambient atmosphere[9] and the water column, influence the chemical and physical properties of water. For instance: pH decreases; salinity decreases; the solubility of solids increases and the solubility of gasses, such as oxygen, decreases; diffusion rates increase; and the rates of biochemical processes initially increase as water temperatures start to rise. When water temperature and nutrient concentrations increase, primary production is stimulated, leading to eutrophic[57] conditions and algal blooms [Mooij, et al., 2007], especially within stratified reservoirs that act as nutrient traps [Schmutz & Sendzimir, 2018].

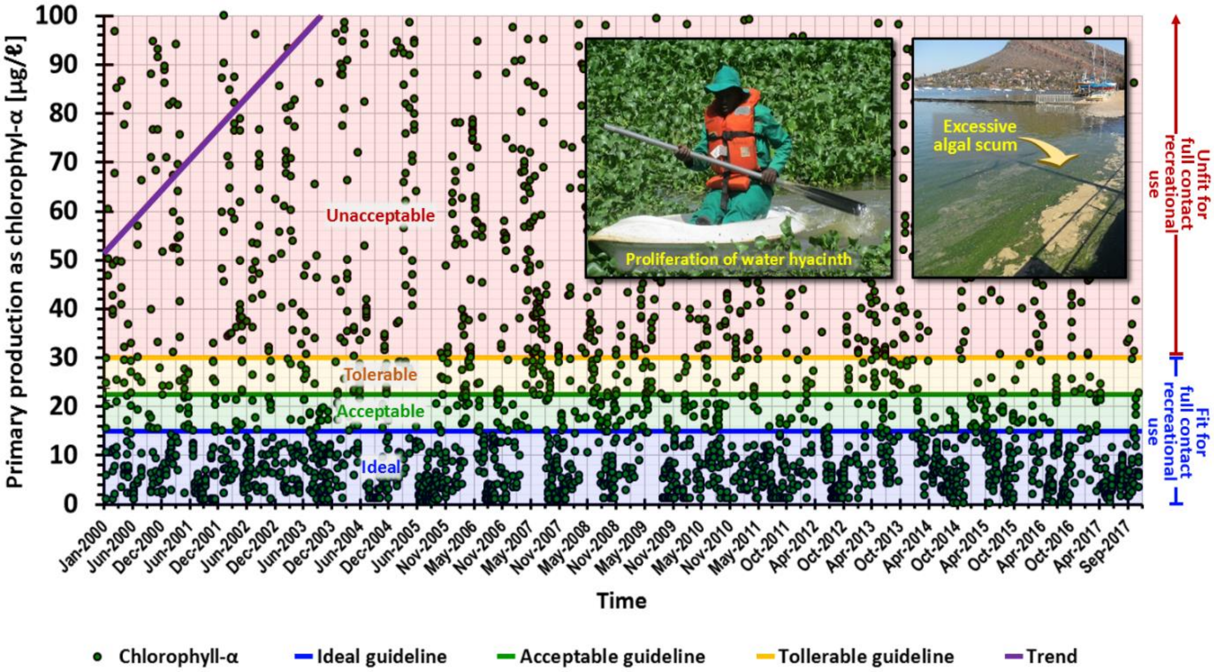

FIGURE 5: Excessive primary production in the epilimnion, measured as chlorophyll-α concentrations per single sample, has an adverse effect on recreational water use in the Hartbeespoort Dam.
Insert photos: © P. Venter.

As temperatures rise, precipitation is not expected to change uniformly. In areas with projected higher precipitation, it is possible that intense precipitation events will occur and cause more erosion and resuspension of sediments and mobilisation of diffuse sources of pollution[38], ultimately resulting in higher concentrations of sediments and nutrients ending up in receiving water resources [Whitehead, et al., 2009; Vogel, et al., 1999]. In areas with projected lower precipitation, it is possible that lower minimum flows, coupled with higher rates of evaporation and evapotranspiration, will occur, resulting in less dilution capacity in receiving water resources. As a result, increased concentrations of contaminants can cause deoxygenation, by lowering dissolved oxygen (DO)[39] concentrations and increasing biological oxygen demand (BOD). Consequently, the risk of eutrophication, especially in water resources with limited re-aeration capacity, will be increased. Therefore, under climate change conditions and due to the alteration of regional precipitation patterns, water resources can be expected to be exposed to increased nutrient-loading, which can ultimately lead to increased primary production and hypertrophic conditions [Whitehead, et al., 2009].

Global warming and solar radiation have mutual connections. As an important source of energy, solar radiation drives photosynthesis in most ecosystems and is an essential factor for the growth of phytoplankton and other aquatic plants. If phytoplankton and aquatic plants do not receive enough sunlight, they start to consume oxygen leading to the depletion of DO in the water column. Under anaerobic[4] conditions, phosphorus released from sediments can lead to eutrophication. Algae distribution is also dependent on the intensity of solar radiation received at different depths, resulting in increased algae growth up to a maximum growth rate [Craig, et al., 2014].

The wind will also be affected by climate change and will have direct and indirect effects on the trophic status[145] of water resources. The direct effects of wind include the blowing of surface algae to shores, forming thick algal mats and changing environmental conditions. The indirect effect relates to the mixing effect created in the water column that enhances the mixture of nutrients and accelerates the release of nutrients from sediments. Also, as the air temperatures rise, wind mixes the warmer upper layers of water with the colder lower layers, which can speed up solubility, diffusion and transformation of pollutants. Changing wind action can also cause inversion[76] of stratified layers[139] in water columns to occur more or less frequently, causing oxygen starvation near the water surface. On the other hand, intense and high-speed winds can also restrain the formation of algal blooms by dissipating algal blooms and weakening their aggregation [George, et al., 2007].

Therefore, poor trophic conditions[145] in water resources are likely to be exacerbated by climate change; the protection of our invaluable water resources in a changing climate is a big and significant challenge for policymakers today, and deserves considerable attention for the sake of future generations. However, three important questions related to eutrophication in a changing climate remain to be addressed, *viz.* (1) Which are the critical climate change factors that most affect eutrophication in freshwater[62] ecosystems; (2) How to completely differentiate the impact of climate change from that of anthropogenic activities on eutrophication and feedback mechanisms; and (3) What are the best and most feasible adaptation counter-measures for dealing with climate change effects on eutrophication? [Nazari-Sharabian, et al., 2018].

1.1.4 Inequities in relation to access to safe sanitation (against the backdrop of a growing population)

The provision of safe sanitation is a key requirement for sustainable and healthy communities. It is critical in the protection of water resources, in the promotion of social and economic benefits that are aligned to national development goals [NPC, 2012] and in meeting the human rights [RSA, 1996] of all who live in South Africa.

While population growth is on average 1.2% per annum, it varies from negative to positive across communities. The growth in the number of households, however, is much higher and is currently at around 3% per annum, nationally. This is due to migration, mainly urbanisation. Urbanisation continues to increase the demand for sanitation provision, with many rural people moving to urban centres in search of jobs and improved services. The demand for sanitation provision can also be attributed to the dedicated housing programme of government that *inter alia* lead to the sub-division of previous large households. Additionally, while only 33% of the population currently live in rural areas, they represent 81% of the national count of settlements due to their often small and scattered nature, making it spatially challenging to provide a good coverage of sanitation services to all [DWS, 2018b; Stats SA, 2016].

Baseline figures on access to reliable sanitation service delivery are regularly surveyed by Statistics South Africa through the national census and through their General Household Surveys. Since 1994, and particularly after 2001, an estimated 5.15 million households have been provided with safe and acceptable sanitation facilities. In 2008, approximately 27% of the population received sanitation services, below the Reconstruction and Development (RDP) standard (**FIGURE 6**). [Schreiner & Hassan, 2011].

The backlog in 1994 was estimated at 4 million households, whereas in April 2017 it was estimated that there were still 3.96 million unserved households [DWS, 2018b]. The South African population increased from around 40 million, in 1994, to a total of 55.6 million, as recorded in the 2016 Census [Stats SA, 2016]. Progress in the reduction of this backlog has been hampered by the substantial population growth and by households becoming smaller (*i.e.* growing at a faster rate than the population). It is estimated that approximately 14.1 million people do not have access to safe sanitation in South Africa, today [DWS, 2018a]. The sanitation crisis threatens the health and well-being of the poor and the vulnerable in South Africa, while also contributing towards eutrophication of water resources – and also retarding the country's economic growth.

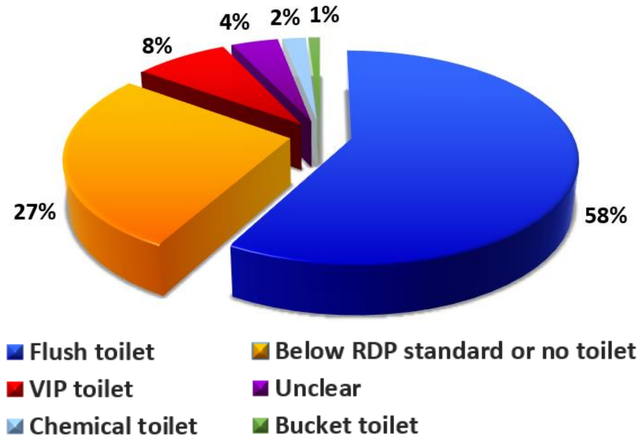

FIGURE 6: Access to sanitation in South Africa, 2008 [Stats SA, 2007; DWAF, 2008].

1.1.5 Water use regulation that is not consistently and/or adequately protecting South Africa's water resources against anthropogenic eutrophication

In the Republic of South Africa, government is constituted of national, provincial and local spheres. These spheres of government are distinctive, interdependent and interrelated [RSA, 1996, S.40(1)].

The Constitution of the Republic of South Africa, 1996 (Act No. 108 of 1996)[5] designates the executive authority to provide water and sanitation services to local government [RSA, 1996, S.156(1)(a)]. In terms of the Water Services Act, 1997 (Act No.108 of 1997), Water Services Authorities (WSAs), *i.e.,* the relevant municipalities, are accountable for ensuring access to water and sanitation services in their areas of jurisdiction. It is expected that WSAs, through Water Services Providers (WSPs), ensure access to safe water and dignified sanitation services [RSA, 1997].

The lawfulness of discharging water containing waste, including municipal wastewater, is essentially determined by whether such a discharge is permissible in terms of the NWA (36:1998) and whether it complies with applicable authorisation requirements, such as relevant Waste Discharge Standards (WDSs)[149]. These discharges should be conducted in accordance with the conditions, as stipulated in: the Municipal Approval (in the case of Schedule 1 water use); or an authorisation issued within a 24-month period prior to 30 September 1998 (in the case of an Existing Lawful water Use[59]); or any General Authorisation (GA); or any water use licence in question; or an alternative authorisation, if dispensing with the requirement for a licence to be issued under the NWA (36:1998) [RSA, 1998, S.22(1)].

One of the biggest causes of excessive nutrient enrichment[100] in water resources by a single water use sector in the country can be ascribed to poor municipal wastewater handling [Harding, 2017; Mudaly & van der Laan, 2020]. The socio-economic impacts associated with poor resource water quality can be

[5] Hereafter referred to as the Constitution (108:1996).

severe. The authorisation of municipal water uses and the enforcement[50] of conditional water use authorisations thus are critical!

Although the Constitution (108:1996) calls on all spheres of government and all organs of state within each sphere to co-operate with one another in mutual trust and good faith by fostering friendly relations; assisting and supporting one another; and avoiding legal proceedings against one another [RSA, 1996, S.41(1)(h)], the Constitution also grants citizens specific rights to access sufficient water, an environment[51] not harmful to health and well-being and the protection of the environment from degradation [RSA, 1996, S.27 and 24]. The right to basic sanitation is not an explicit constitutional right. However, the right to sanitation could be derived from the right to a clean environment, read together with the right of access to clean water. Many other constitutional rights in the Bill of Rights overlap with, and support the rights to water supply and sanitation services. These include the rights to equality, dignity, access to information and just administrative action [Algotsson, et al., 2009, p. 2].

The NWA (36:1998) designates the authority to act as the trustee of the nation's water resources to the National Government, acting through the Minister of Water and Sanitation to ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all persons [RSA, 1998, S.3(1)]. Part of the purpose of the NWA (36:1998) is to prevent and to reduce pollution[155] and degradation of water resources [RSA, 1998, S.2(h)]. Any person that unlawfully and intentionally or negligently commit any act or omission which pollutes or is likely to pollute a water resource is guilty of an offence [RSA, 1998, S.151(1)(i)]. The Act, further, compels responsible authorities to give effect to any determination of a class of a water resource and the associated Resource Quality Objectives (RQOs)[125] [RSA, 1998, S.15] in order to ensure that South Africa's water resources remain fit-for-use.

Although the legislation should be applied in a just, fair and consistent manner to both private and public sector water users alike, the Constitution (108:1996) also places an obligation on national and provincial governments to, by legislative and other measures, support and strengthen the capacity of municipalities to manage their own affairs, to exercise their powers and to perform their functions [RSA, 1996, S.154(1)]. The intention, however, was not to make it possible for municipalities in contravention of environmental legislation to avoid accountability through continuously appealing for support, especially in cases where such support is required post compliance monitoring[27] and enforcement, as undertaken by the Department of Water and Sanitation (DWS).

A notable degree of dysfunction exists in many municipalities, for a range of institutional, technical and/or management incapacity, financial and political reasons [DWS, 2017a]. The fact that up to 828 WwTWs (**FIGURE 7**) could not achieve Green Drop certification in 2021, is a reflection of the poor condition of municipalities in South Africa [DWS, 2022]. There is an urgent need to address issues of accountability, coordination and leadership, poor cooperative governance and inadequate cross-regulatory interfacing with the DWS, as well as the appropriate actions to be put in place where WSAs show consistent failure in the delivery of universal and reliable water services.

Challenges with the authorisation of water use, that have significant impacts on aquatic ecosystems and other receiving water users, include–

- the prevalence of water uses that are not permissible under the NWA (36:1998);
- incidences of poor authorisation administration;
- lack of regulatory integration and poor cooperation amongst relevant authorities;
- periodic backlogs with the issuing of water use authorisations;
- poor quality of some water use authorisations (*e.g.*, authorisation conditions that do not appropriately integrate with water resource requirements), and ELU with water use authorisations that contain inadequate or outdated conditions; and
- poor compliance with water use authorisation conditions, often coupled with insufficient compliance monitoring and/or inadequate enforcement.

Annexure A provides a summary of: some eutrophication-related pollutant parameters; associated water user concentration requirements; and effects on human and aquatic ecosystem health, and other water users (should such pollutants be present at unacceptable high levels in receiving water resources).

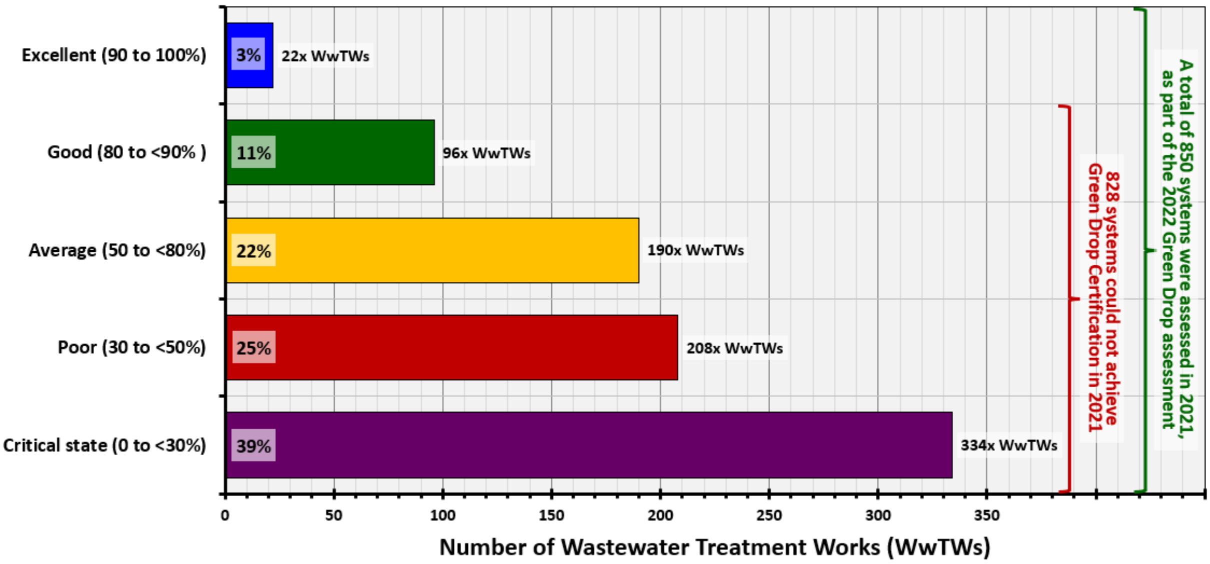

FIGURE 7: **Wastewater Treatment Works that have been awarded different Green Drop scores, ranging from *"excellent"* to *"critical state"* [DWS, 2022].**

1.1.6 Lack of skilled water scientists and engineers

Skilled water scientists and engineers are indispensable to the development and implementation of eutrophication management solutions. This is particularly true when dealing with complex systems (*i.e.,* having to engineer infrastructure solutions, conducting multi-criteria decision-making, executing forward planning, or devising interventions that integrate with receiving water resource requirements). In the battle against water pollution and eutrophication, the value of skilled water scientists and engineers is essential as these experts are resources to be drawn upon by both the public and private sectors, including civil society.

In the public sector, the DWS (as the sector leader) and local government (as the Water Services Authorities), are key role-players that must collectively oversee and regulate the entire water value chain up to before the coastal marine water environment. Several other public water institutions (such as the Water Services Providers, the Water Boards, the Catchment Management Agencies and the Water User Associations) must also be suitably staffed to complement the water resource and water services functions of government, especially with respect to implementation of progressive measures. In the private sector, knowledgeable scientists and engineers must see to environmental compliance management, engineering of infrastructure solutions and development of innovative approaches to address technical challenges.

The water sector is both inter-sectoral and multi-disciplinary in nature [DWS, 2018b, p. 11.1]. When dealing with eutrophication at **inter-sectoral level**, collaboration is necessary among sectors, such as water and sanitation; agriculture; health; education; forestry; aquaculture; industry; mining and environment; and government (be it national, provincial or local government). From a **multi-disciplinary** perspective, collaboration is necessary across a range of focus areas (to name but a few, policy and regulation; planning and information; capital works design, construction, operation and maintenance; ecological protection; chemistry and microbiology; social and economic analysis; financial and project management).

In 2015, the Water Research Commission (WRC) conducted a sample public sector skills gap analysis with the aim of developing an integrated water sector skills intervention map. The skills gap analysis distinguished between *"capacity"* (which was used in the context of the number of staff per job title within an institution) and *"skills"* (which referred to the ability of individuals). The capacity and skills gaps were determined by subtracting the supply from the demand (*i.e.,* by considering the capacity necessary *vs.* capacity available). The skills gap was determined by comparing necessary skills *vs.* skills available to manage water resources and services. It was found that the capacity gaps for the analysed Catchment Management Agency (CMA) and local municipality were 44% and 92%, respectively, and the skills gaps for the analysed CMA, water board and local municipality were 36%, 60% and 55% respectively [Vienings, et al., 2015, p. 220]. In a staff members' own rating exercise to analyse available skills in the DWS, a rating of 71% was recorded [Win-SA, 2015, p. 9]. The vacancies in technical departments of water institutions that were analysed, averaged at 24% [Vienings, et al., 2015].

In local government, about 144 municipalities have been assigned the function of Water Services Authorities (WSAs). At least 33% of municipalities are regarded as being dysfunctional while more than 50% have very limited to no technical capacity [DWS, 2018b] – this in spite of legal requirements that, as an example, the process control function at Wastewater Treatment Works (WwTWs) must be performed by skilled personnel [GN R.813, 2013; GN R2834, 1986].

It is critical to define skills and capacity building beyond individual capacity (**FIGURE 8**) to include organisational capacity and an enabling environment [Morgan, 1998]. Capacity at the individual level is the most fundamental element of capacity. It becomes the foundation for organizational capacity and refers to the will and ability of an individual to set objectives and to achieve them using their own knowledge and skills. Capacity at the organization level will determine how individual capacities are utilized and strengthened. It refers to anything that will influence an organization's performance. Capacity at the environment level refers to the environment and conditions necessary for demonstrating capacity at the individual and organizational level [JICA Task Force on aid approaches, 2004, p. 16].

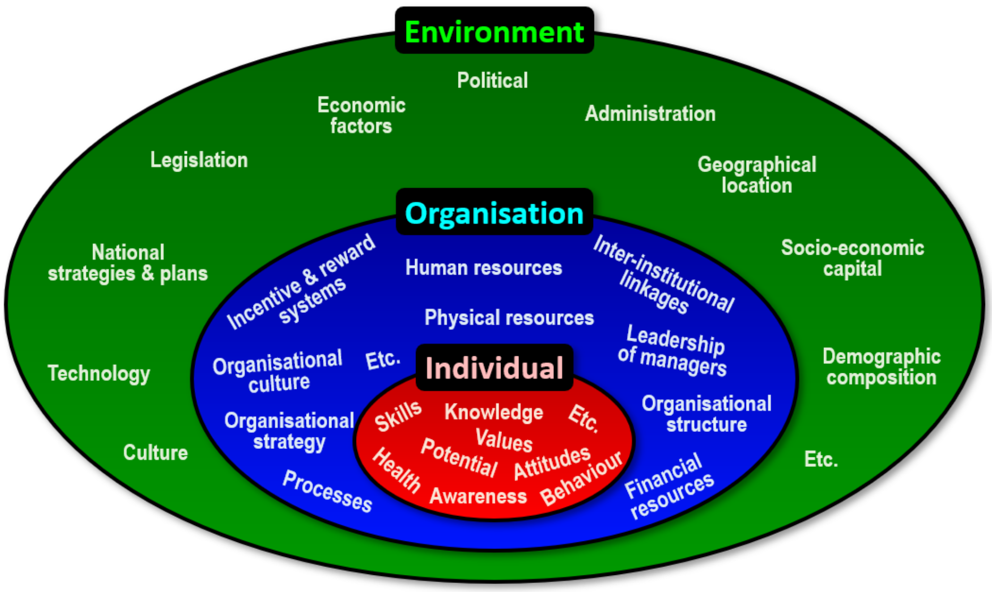

FIGURE 8: Levels of capacity [Adapted from Matachi, 2006].

Data from the Department of Higher Education and Training's (DHET) management information system (HETMIS) showed that the supply of Civil Engineering graduates doubled over a five-year period from approximately 1 000 to 2 000 graduates per year. The number of other graduates with qualifications that apply to the water sector also increased dramatically over the same period. Although the supply of science graduates has improved significantly, water institutions still lack skilled water scientists and engineers, and the inadequate environment and organisational capacities associated with many of these water institutions continue to hinder effective service delivery [Van Baalen, et al., 2015].

Eutrophication management capacity has become diminished throughout the country as staffing transformation and human resource turnover within institutions has meant that there is limited background knowledge or practical experience of the problem. There have been few capacity-building special projects aimed at rehabilitating the eutrophication status of any aquatic system. The country has regressed in terms of its capacity and ability to deal with eutrophication [Moss, 1999].

A progressive water sector requires skilled individuals empowered by a conducive organisational culture and an enabling external environment that supports excellence and *"Batho Pele"* principles[6]. Without necessary intervention, poor service delivery trends in many water institutions are likely to continue (such as increased procrastination and growing incidences of fruitless, wasteful, irregular and unauthorised expenditure of public funds [Muller & Erasmus, 2020].

1.2 Problem declaration and potential policy and strategy responses

Causal chain analysis [Rogers, 2000], often also called root cause analysis [Rooney & Van den Heuvel, 2004], is closely related to systems thinking[141] [Arnold & Wade, 2015], life cycle assessment[78] [Guinee, et al., 2011] and the Driver-Pressure-State-Impact-Response (DPSIR)[41] approach [Kristensen, 2004]. At its most basic, a causal chain is an ordered sequence of events linking the causes of a problem with its effects. Each link in the causal chain is created by repeatedly answering the question: *"Why?"*

FIGURE 9 [7] shows a simple theoretical causal chain example for phosphorus loading of receiving water resources. Note how the causes of water quality issues, as well as their ultimate effects, almost always reside within the socio-economic domain, implying that poorly planned and un-managed human development and progress are often the enemy of prosperous and healthy societies.

FIGURE 9: Example of a possible causal chain for phosphorus loading.

[6] *"Batho Pele"* is Sotho-Tswana for *"People First"*. The Batho Pele White Paper is national government's White Paper for Transforming Public Service Delivery [DPSA, 1997].

[7] More complex causal chains are usually depicted in tree-format with a particular *"cause"* that can branch-off into one or more *"effects"*. The numbering of the cause-and-effect elements in **FIGURE 9** reflects this relationship. *"Cause"* 9 branches-off into *"Effects"* 10.1 up to 10.3. *"Effects"* 11 can follow on from any of the *"Causes"* 10.1 through to 10.3. The *"effect"* following a preceding *"cause"*, constitutes the *"cause"* of the next *"effect"*, forming a causal chain.

The **D**river-**P**ressure-**S**tate-**I**mpact-**R**esponse (DPSIR) framework constitutes a structured approach to describe environmental problems, by defining relationships between anthropogenic activities and the environment [Smeets & Weterings, 1999, p. 7]. According to the DPSIR framework, there is a chain of causal links, starting with *"driving forces"*, leading to *"pressures"*, that alter the *"state"* of bio-physico-chemical[16] conditions, causing *"impacts"* on the environment and eventually necessitating appropriate policy, strategy and/or political *"responses"* [Kristensen, 2004].

An analysis of eutrophication in South Africa, based on the DPSIR framework and, in part, utilising input obtained from a country-wide survey which involved the nine DWS regional offices having completed questionnaires that addressed areas concerning eutrophication policy and strategy [Walmsley, 2003], is presented in **TABLE 1**.

TABLE 1: An analysis of anthropogenic nutrient enrichment and the effects of eutrophication in South Africa, based on the DPSIR framework.

DRIVER ⇨	**PRESSURE ⇨**	**STATE ⇨**	**IMPACT ⇨**	**RESPONSE ↺**
i.e., the socio-economic or demographic developments, OR production or consumption practices that trigger *"pressures"*.	*i.e.*, the anthropogenic activities that disturb the *"state"* of ecosystems.	*i.e.*, the physical, chemical or biological condition of ecosystems that causes *"impacts"* on the environment.	*i.e.*, effects on habitats, biota, ecosystem goods and services and ultimately society that require control, management and/or mitigation, through appropriate responses.	*i.e.*, the societal measures aimed at preventing, minimising or mitigating negative *"impacts"* by feeding back to the *"drivers"*, *"pressures"* and *"state"* [8]
Mining: ▶ Opencast mines to supply demand for minerals; and ▶ Underground mining operations to supply demand for minerals.	▶ Blasting; ▶ Exposing of phosphorus bearing rock; and ▶ Disturbance of habitat and soil layers.	▶ Soil properties, such as pH, affects P availability. Under some condition a high soil pH can increase P mobility and availability, whereas, acid precipitation can reduce P mobility, holding P back until the pH rises again; ▶ Water properties, such as pH, temperature and O_2 affect the $NH_3 \leftrightarrow NH_4^+$ equilibrium. Free un-ionised ammonia (NH_3) is toxic to aquatic organisms and predominates when the pH and water temperatures are high, or when O_2	▶ Shading leads to benthic habitat destruction; ▶ Fish and other aquatic animals become stressed, and are susceptible to parasites; ▶ Aquatic animals are subjected to bacterial infections; ▶ Excessive algal blooms are harmful to, and lead to injury of aquatic animals, such as the clogging of fish's gills, poisoning by toxin releases, and localized anoxia[5] that effects	**IMPLICATIONS FOR POLICY FORMULATION:** **Chief imperatives:** ▶ Limit anthropogenic nutrient-loading; ▶ Reduce excessive primary production; ▶ Protect aquatic ecosystems and their biological diversity; ▶ Secure water resources that are fit-for-use; and ▶ Support ecologically sustainable development and justifiable socio-economic growth.
Industry: ▶ Industrialisation and industrial expansion; ▶ More industrial waste and wastewater; and ▶ Growing potential for air pollution.	▶ Discharge of substandard wastewater; ▶ Atmospheric emissions of NH_3 and NO_2 affecting the nutrient content of precipitation; ▶ Atmospheric emissions of NO_2 and SO_2 generating acid precipitation; and ▶ Habitat disturbance.			

[8] After examining the identified responses, they were grouped according to their nature, *i.e.* (1) those that typically support policy formulation vs (2) those that typically support strategy establishment. The policy supporting responses were again subdivided into the following sub-groups: (1.1) *"chief imperatives"*; and (1.2) *"complementing imperatives"*. The strategy supporting responses were subdivided according to the following sub-groups: (2.1) *"core approaches"* (as *"source"*, *"resource"* or *"remediation"* directed management); (2.2) *"operational approaches"* (as per the Plan-Do-Check-Act cycle [Moen & Norman, 2009]); and (2.3) *"supporting approaches"*.

<u>D</u>RIVER ⇨	<u>P</u>RESSURE ⇨	<u>S</u>TATE ⇨	<u>I</u>MPACT ⇨	<u>R</u>ESPONSE ↺
Agriculture: ▶ Increased dry-land and irrigated crop production to maintain food security; ▶ More dairies and intensive animal feeding units needed to maintain food security; ▶ Expanding aquaculture to provide an alternative source of protein and to maintain food security; ▶ The intensification of farming practice to maintain a favourable economy of scale and to remain profitable; ▶ A lack of capacity hindering effective farm advisory services; and ▶ Lack of capacity with respect to on-farm best management practices.	▶ Poor fertilising practices and over-fertilising causing fertilizer-laden diffuse[38] runoff from agricultural fields; ▶ Prevalence of erosion, mobilising sediments on which chemical elements[49] are adsorbed; ▶ Over-irrigation to satisfy leaching requirements; ▶ Feedlot waste disposal and wastewater discharged; ▶ Habitat disturbance; ▶ Organic waste, food leftovers, and excreta associated with aquaculture; ▶ Inadequate farm advisory and extension services; and ▶ Poor farming practices.	levels are low (*i.e.*, low O_2 levels inhibit nitrification). Factors, such as alkaline drainage, thus, may have an aggravating influence; ▶ Elevated P; ▶ Elevated N, also in groundwater resources that feed surface water resources; ▶ Elevated Chl-α; ▶ Occurrences and intensity of nuisance algal blooms; ▶ Occurrences of floating and rooted aquatic macrophytes[79]; ▶ Native plant species loss and replacement with alien invasive plant species; ▶ Dominance of cyanobacteria and the occurrence of toxic cyanobacteria; ▶ Undesirable aesthetic conditions (*viz.* discolouration, increased turbidity and loss of clarity, foaming, presence of odours, etc.); ▶ Impoundments sequester nutrients; ▶ Sequestration of nutrients in the sediment; ▶ Severe shading and light attenuation caused by excessive macrophyte growth, blooms of macro-algae and phytoplankton, and the presence of debris hinder the photosynthetic processes in benthic plants;	subsistence and sports fishing; ▶ Changes of ecological community structure and loss of biological diversity; ▶ The proliferation of alien invasive plant species affects resource water quality through reduced dilution capacity, and altered nutrient cycling; ▶ Increased occurrences of taste and odour problems in final drinking water; ▶ Increased water treatment costs to run water treatment works (WTWs) to remove odours, tastes, toxins, etc.; ▶ Toxic levels of free ammonia (NH_3) may kill fish and other aquatic organisms; ▶ Inorganic chemicals, such as ammonia, nitrites, hydrogen sulphide, etc. that induce the formation of harmful substances, such as nitrosamines, suspected of being mutagenic[91], during the production of potable water; ▶ The sequestration of nutrients in impoundments reduces the downstream transfer of nutrients to floodplains, wetlands, lakes and the coastal marine environment; ▶ The destruction of habitat and ecological infrastructure, such as wetlands, may liberate and	**<u>Complementing imperatives</u>:** ▶ Resource eutrophication management; ▶ Promote research; ▶ Promote management cooperation; ▶ Promote transparency; and ▶ Facilitate capacity building and the empowerment of role-players. **<u>IMPLICATIONS FOR STRATEGY ESTABLISHMENT:</u>** **<u>Core approaches</u>:** **Source[136] Directed Management:** ▶ Improved regulation; ▶ Operationalising of the Receiving Water Quality Objectives Approach; and ▶ Integration across sectors. **Resource[123] Directed Management:** ▶ Determine Resource Directed Measures; and ▶ Improved regulation. **Remediation[121] Directed Management:** ▶ Develop and implement a Remediation Strategy to address cases of legacy nutrient pollution; and ▶ Improved regulation.
Tourism: ▶ Seasonal trends peaking during holiday periods; and ▶ Increased demands for water services during peak times.	▶ Fluctuating and increased waste and wastewater production; and ▶ Fluctuating and increasing pressure on urban wastewater handling.			
Local government: ▶ Growing and deteriorating industrial wastewater handling, feeding municipal sewer network systems; ▶ Deteriorating urban wastewater handling; and ▶ Waste management.	▶ Inadequate operation and maintenance of offsite and onsite sanitation systems; ▶ Theft and vandalism of wastewater infrastructure; ▶ Discharge or loss of untreated and/or substandard wastewater; and ▶ Poor waste practices.			

DRIVER ⇨	PRESSURE ⇨	STATE ⇨	IMPACT ⇨	RESPONSE ↺
Human settlement areas: ▶ Expansion of paved areas and generation of stormwater.	▶ Nutrient-laden diffuse runoff from built-up areas; and ▶ Habitat disturbance.	▶ Elevated COD; ▶ Oxygen depletion, especially in the deeper layers of water resources during the end of summer; ▶ Loss of benthic diversity affects and lead to stressed bottom-feeding fish and other animals; ▶ The decomposition of organic matter leads to an over-supply of CO_2, which, in turn, also enhances water acidification; ▶ Increased occurrences of elevated levels of hydrogen sulphide and heavy metals in deoxygenated hypolimnia; ▶ Increased fish and invertebrate stress ▶ Undue exposure to pathogens that are present and associated with faeces; and ▶ Diminishing state of ecological infrastructure.	reintroduce previously sequestered pollutants back into receiving water resources; ▶ Increased occurrence of human health problems (*i.e.*, gastroenteritis, skin irritations, etc.); ▶ Increased incidence of Bilharzia, due to increased habitat, which may be associated with the proliferation of aquatic plants and macrophytes; ▶ Increased interference with recreational activities (*i.e.*, boating, fishing, swimming, etc.); ▶ Increasing risk to human health affecting traditional ceremonies and rituals performed in rivers and wetlands; ▶ Struggling tourism due to foul odour and turbidity issues, skin irritations, etc.; ▶ Loss of property values; ▶ Interference with irrigation and livestock agriculture (*i.e.*, clogging of irrigation nozzles and livestock mortalities); ▶ Mortality of domestic and wild animals, drinking hypertrophic waters that contain toxins; ▶ Reduced income from agriculture, tourism	**<u>Operational approaches</u>:** **Plan:** ▶ Holistic water resource system and catchment planning; ▶ Structured planning to ensure that WwTWs are timeously upgraded to not exceed design capacities; ▶ Validation and verification (V&V) of all water uses with a water quality impact potential; and ▶ Waste load accounting to be introduced as a planning measure. **Do:** ▶ Integration of authorisation conditions with water resource requirements; ▶ Increased reuse and recycling of waste and water containing waste; ▶ Revision of nutrient discharge standards; ▶ Ensure that all water uses with a potential to contribute towards eutrophication are permissible, compliant and lawful; ▶ Improved water use authorisation and administration; ▶ Improved regulation; ▶ Enforcement of conservation agriculture;
Other land uses: ▶ Establishment of more golf courses.	▶ Fertilizer and nutrient-laden diffuse runoff from golf courses; and ▶ Habitat disturbance.			
Population dynamics: ▶ Depopulation of rural areas; ▶ Constant stream of foreign nationals in search of a better future moving to South Africa; ▶ Increasing urbanisation; ▶ Increasing development; ▶ Replacement of ecological infrastructure with grey infrastructure; ▶ Growing demands for potable water and water resource development; ▶ Demand for western style foods and fast foods, *e.g.*, growing consumption of meats; ▶ Use of phosphate-free detergents; ▶ Escalating unemployment; and ▶ Inadequate levels of education or less skilled and aspiring employees being absorbed.	▶ Habitat disturbance; ▶ Increased urban waste production; ▶ The nutrient-loading character of wastewater is changing; ▶ Pressure on urban wastewater handling; ▶ Negative effect on the affordability of rural water services infrastructure, affecting operation and maintenance; ▶ Altered flow and water quality regimes associated with the establishment of impoundments and related infrastructure; ▶ Lack of skilled water scientists and engineers; and ▶ Inadequately capacitated water institutions.			

DRIVER ⇨	PRESSURE ⇨	STATE ⇨	IMPACT ⇨	RESPONSE ↺
Climate variability: ▶ Extended dry spells; ▶ Extended hot spells; ▶ Extreme wind action; ▶ Increasing demands for water resource development; and ▶ Potentially changing climatic conditions.	▶ More frequent mixing of stratified layers and inversion of epilimnion[55] and hypolimnion[70] may lead to more regular recycling of nutrients from the anaerobic hypolimnion; and ▶ Exacerbated poor trophic conditions.		and other effected sectors; ▶ Impaired social development; and ▶ Economic loss.	▶ Enforcement of buffer zones and other best management practices; and ▶ Implementation of the Waste Discharge Charge System. **Check:** ▶ Improved monitoring[90] programmes and reporting for local and national government; ▶ Regular and targeted compliance monitoring; and ▶ Appropriate information management systems are in place. **Act:** ▶ Effective enforcement of big and regular offenders; ▶ Rehabilitation and restoration of ecological infrastructure; ▶ Rehabilitation of hard infrastructure; and ▶ Adequate maintenance of water resource and services infrastructure. **Supporting approaches:** ▶ Skills development training and capacity building; ▶ Appointment of employees, who possess appropriate skills levels, in technical positions; ▶ Research and technology development;
Administrative and political instability: ▶ Fading institutional capacity in many government departments and agencies; ▶ Failing corporate management and governance; ▶ Systemic corruption; ▶ Escalating collapse of local government; ▶ More frequent service delivery protests; and ▶ Shrinking availability of funds or capital (capex) and operational expenditure (opex).	▶ Exceeding the design capacity of WwTWs; ▶ Destruction of water resource and services infrastructure; ▶ Failing operation and maintenance of water resource and services infrastructure; ▶ Discharge of untreated and/or substandard urban wastewater; and ▶ Operating rules for the water resource infrastructure that promote enrichment.			

DRIVER ⇨	PRESSURE ⇨	STATE ⇨	IMPACT ⇨	RESPONSE ↺
Poverty and criminality: ▶ Increasing vandalism of water services infrastructure; and ▶ Declining affordability of social infrastructure.	▶ Washing in streams and in rivers; ▶ Inappropriate onsite sanitation and bush-toileting; ▶ Theft and destruction of sanitation services infrastructure; ▶ Overflowing utility access holes caused by sewer system blockages and sabotage; and ▶ Discharge of untreated and/or substandard urban wastewater.			▶ Creation of an informed, supportive and responsible public; ▶ Behavioural change communication programmes to facilitate behavioural change and a sense of responsibility in communities aimed at limiting and preventing excessive nutrient-loading; and ▶ Management participation and cooperative governance.

TABLE 1 provides a succinct definition of the eutrophication problem in South Africa, which incorporates causes, effects and their causal relationships in tabular format. Additionally, **TABLE 1** provides a *"bridge"* between *"problem"* and *"potential solution"* (addressed in Parts 2 and 3 of this document) by proposing potential eutrophication management policy, strategy and intervention solutions in the last column. These potential solutions are to be developed further in Parts 2 and 3 of this document, in order to establish a concrete framework for the reduction of excessive nutrient enrichment of water resources and the control of anthropogenic eutrophication in South Africa.

The above summation of causes, effects and challenges that are associated with over enrichment and the occurrence of hypertrophic conditions in water resources in South Africa, has highlighted multiple inter-causal-linkages. **FIGURE 10** is a graphical representation of some of these inter-causal-linkages. Most importantly, it has been shown that uncontrolled, and poorly planned and managed development ultimately affects the sustainability of such development to the detriment of society. The cumulative effects of water pollution on aquatic ecosystems, society and the economy are significant, and measures need to be put in place to control and to manage the occurrence of anthropogenic eutrophication.

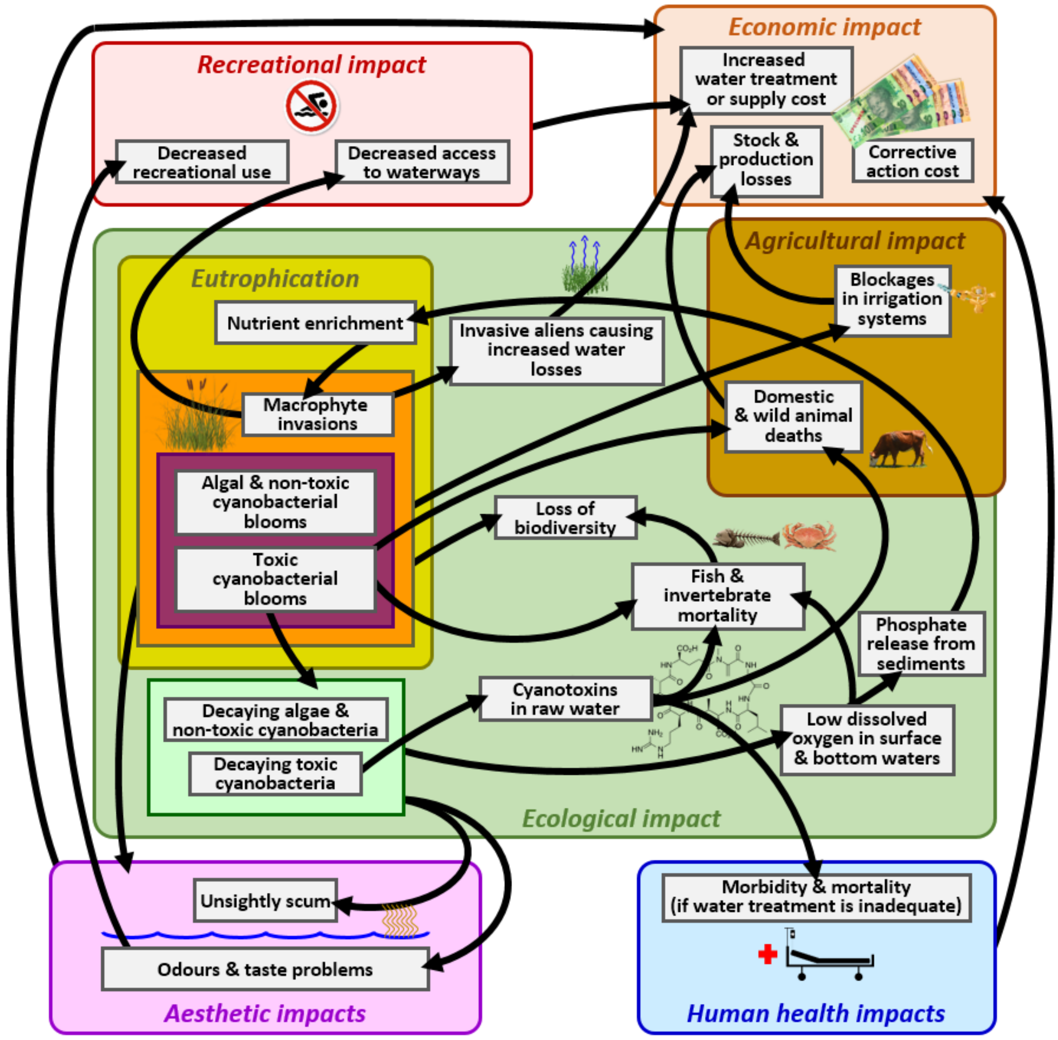

FIGURE 10: Prominent detrimental impacts associated with eutrophication [Adapted from DWAF, 2002].

South Africa has about 56 million inhabitants who live in more than 28 thousand communities [Stats SA, 2016]. All the citizens in each of these communities have basic rights that are guaranteed in the Constitution (108:1996) through the Bill of Rights, which enshrines the rights of all people in South Africa and that affirms the democratic values of *human dignity*, *equality* and *freedom* [RSA, 1996, Bill of Rights: Section 7(1)]. The slogan: ***"Water is life! Sanitation is dignity!"*** is the embodiment of the contribution of water, as a common good, towards achieving these lofty democratic values. Eutrophication is incompatible with these values, and, thus also with the slogan: *"Water is life! Sanitation is dignity!"*. Poor sanitation constitutes a significant source of nutrient over-enrichment that leads to eutrophication which, in turn, is one of leading threats to fitness-for-use of the country's water resources.

CHAPTER 2: DEFINING THE SUBJECT

2.1 Eutrophication

"Eutrophication" is an ecological term used to describe the process by which a waterbody becomes enriched with plant nutrients [Walmsley, 2000, p. 4]. During this process the waterbody accumulates organic matter (both living and decaying) and progressively changes its character from that of a deep waterbody to that of a wetland, and ultimately to that of a terrestrial system. Eutrophication[58] is therefore a term that is primarily associated with the process of natural ageing of lakes [Holdren, et al., 2001]. Under natural conditions this process (**FIGURE 11**) takes place over tens of thousands of years. However, over the last ±100 years, human influences have greatly accelerated the rate of enrichment, thereby shortening the lifespan of waterbodies. Importantly, two types of eutrophication can be distinguished [Walmsley, 2000; Walmsley, 2003], *viz*.:

- ***Naturally occurring eutrophication*** that is dependent on the geology and natural features of a catchment. It is not reversible and continues *ad infinitum*, albeit at a slow rate; and
- ***Human-induced eutrophication*** that is related to anthropogenic activities. Some references also refer to the latter process as *"cultural eutrophication"*, as it is associated with human activities (social and economic) and as it accelerates the rate of ageing of waterbodies. Anthropogenic eutrophication is reversible, albeit at a cost.

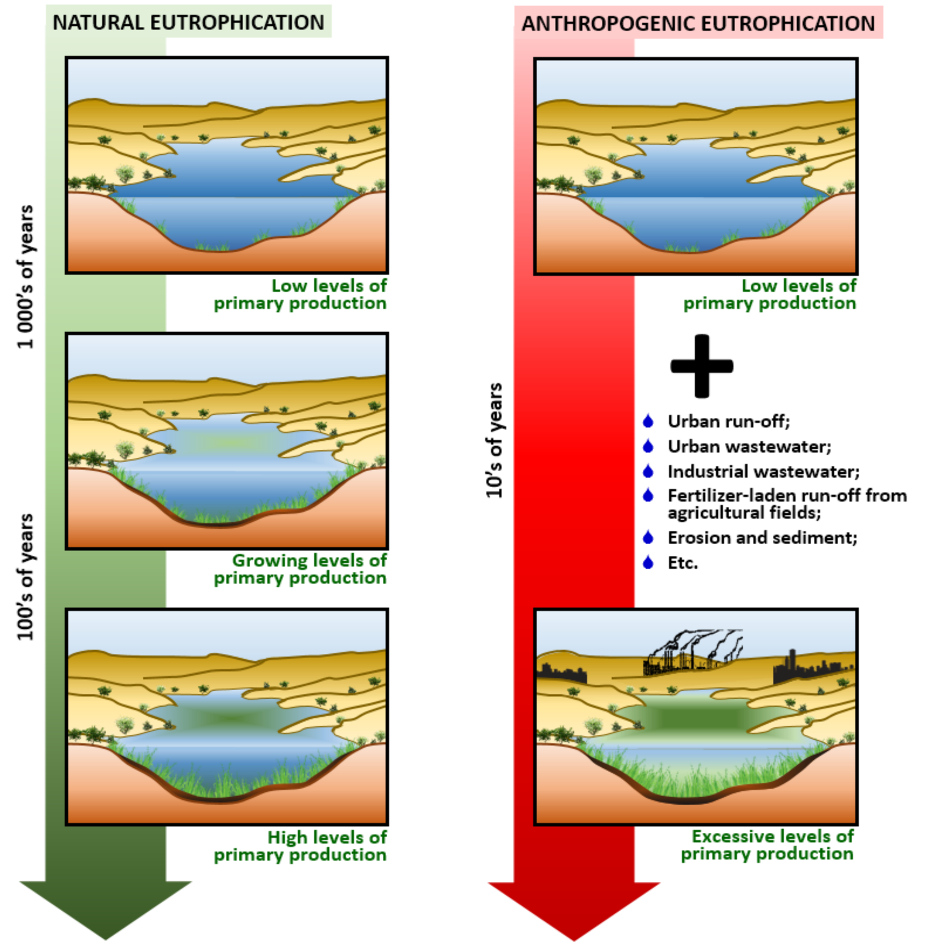

FIGURE 11: Illustration of *"natural"* and *"anthropogenic"* eutrophication [Holdren, et al., 2001, p. 42].

Anthropogenic eutrophication was first recognised as a problematic environmental phenomenon when scientists were able to associate problem conditions in waterbodies with increased nutrient enrichment from human activities [Stewart & Rohlich, 1967; Vollenweider, 1968]. The process of eutrophication also became associated with a wide array of water resource problems [Dunst, et al., 1974]. This led to many definitions of the term and a rather confused understanding of what it meant. One of the most widely accepted definitions of eutrophication is that of the Organisation for Economic Cooperation and Development [OECD, 1982] which describes the process as: ***"... the nutrient enrichment of waters which results in the stimulation of an array of symptomatic changes, amongst which increased production of algae and aquatic macrophytes, deterioration of water quality and other symptomatic changes are found to be undesirable and interfere with water users"***.

By controlling the anthropogenic triggers of excessive nutrient enrichment, eutrophication can be managed. In contrast to anthropogenic eutrophication, natural eutrophication cannot be readily managed, though, in some instances, it may be possible to influence naturally occurring eutrophication with management measures, such as stream-flow manipulation and remediation[121] strategies.

Some see nutrient enrichment as having far wider implications than just water quality problems associated with water resources. This is because of the extent by which anthropogenic nutrient-containing materials impact on continental air, and terrestrial and aquatic eco-systems[7]. Nutrient enrichment, therefore, can be understood to influence sustainable natural resource use (*i.e.* the use of material sources of nutrients), nutrient flow through ecosystems, and multiple impacts on air, land and water [EPA, 2008; EPA, 2001; EPA, 2000a; EPA, 2000b].

In contrast to eutrophication, oligotrophication[104] is *"eutrophication in reverse"* and refer to the process of nutrient depletion[99] and reducing levels of primary production. Oligotrophication can result [Stockner, et al., 2000], *inter alia*, from – the removal of primary nutrient inputs, such as the decommissioning of wastewater treatment works (WwTWs); inter-basin transfers; vegetation clearance and removal; the channelisation and drainage of wetlands and streams; acidification or liming of waterbodies, and soils; etc.

2.2 Nutrients

In the previous discussions general references were made to nutrient-loading[102] as the cause of both natural and anthropogenic eutrophication, to introduce the concept. Next, it is important to clarify the relative importance of the individual nutrient elements in this process.

Living organisms require approximately 40 different nutrient elements, which naturally occur, collectively in both the Earth's crust, *i.e.,* the lithosphere[79], and in the atmosphere, to sustain growth and reproduction. These essential nutrient elements are usually considered in two groups [Harper, 1992], *viz.*:

- ***Macronutrients*** (or major elements), such as calcium (Ca), magnesium (Mg), potassium (K), carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), sulphur (S), iron (Fe), as well as silica (Si), used in cell frustules[63] by diatoms[35] and a few other algal species. These nutrient elements are the most important of the macronutrients, and are required in larger quantities; and
- ***Micronutrients*** (or trace elements), such as copper (Cu), cobalt (Co), molybdenum (Mo), manganese (Mn), zinc (Zn), boron (Br), vanadium (Va), chlorine (Cl), selenium (Se) and vitamin complexes, being the most important of the micronutrients, are required in smaller quantities.

The most important nutrient element, carbon, is usually considered separately from the others, because it is the energy locked into the chemical bonds between carbon atoms and those with oxygen and hydrogen atoms, which is the basis of the photosynthetic conversion of solar energy into living tissue [Post, et al., 1990]. Additionally, oxygen and hydrogen are freely available in water under most circumstances [Miller, 1998].

Out of all the nutrient elements derived from the lithosphere[79], and that are present in plant tissue, phosphorus and selenium are those whose proportional abundance is lower in the lithosphere than in plant tissue [Harper, 1992]. Phosphorus, thus, is a prime candidate for a macronutrient that would potentially limit primary production. Selenium, followed by zinc, molybdenum and manganese are potentially likely to be limiting micronutrients [Atlas & Bartha, 1987].

Out of all the nutrient elements derived from the atmosphere or hydrosphere[68], such as carbon, nitrogen, oxygen and hydrogen – nitrogen[93] is regarded as a prime contender to potentially limit primary production. This is due to nitrogen's prevalent gaseous form, *i.e.* nitrogen gas (N_2), making up the lion's share of nitrogen on the planet, and because nitrogen gas (N_2) cannot be assimilated directly by most plants, whereas carbon is unlikely to be limiting because of its prevalent gaseous form, *i.e.* carbon dioxide gas (CO_2), being water soluble and bio available under most circumstances [Harper, 1992].

Anthropogenic eutrophication and the construction of dams have led to decreased downstream silicate availability and silicate availability for input to estuaries and oceans [Bennekom & Van Salomons, 1981]. Furthermore, phosphorus and nitrogen are recycled more rapidly in the water column than is silicon, and along with increased eutrophication in receiving rivers and estuaries, and in coastal areas, increased P:Si and N:Si ratios are expected [Egge & Aksnes, 1992]. Officer & Ryther (1980) notes that phytoplankton communities can generally be divided into two basic categories, *i.e.* those dominated by diatoms and being dependent on the presence of silicate, and those dominated by flagellates[61] (or non-diatomaceous forms) and normally not being dependent on the presence of silicate. It, thus, is conceivable that the P:Si and N:Si ratios influence the composition of phytoplankton communities, and that low ratios (*i.e.* high silicon availability) is generally being associated with diatom dominance. Additionally, the presence of flagellate communities is often associated with the undesirable effects of anthropogenic eutrophication, while diatom communities are not [Officer & Ryther, 1980]. The presence and composition of diatom communities are indicative of past and present aquatic health conditions and are useful as indicator of resource quality.

2.3 Nutrient cycling and anthropogenic interference

Cycling of the limiting nutrients[98], phosphorus and nitrogen, is discussed next:

2.3.1 Phosphorus

On land, over thousands of years, phosphorus is gradually becoming less available to plants since it is slowly lost in runoff to the marine environment. Humans have caused major changes to the global bio-geochemical phosphorus cycle through mining and the utilisation of phosphorus minerals[87], *inter* alia, as phosphorus fertilizer; in detergents; and also the export of food from farms to cities, where it is lost, *inter alia*, as effluent. Phosphorus does enter the atmosphere in very small amounts when dust is dissolved in rainwater and seaspray, but the element remains mostly on land and in rock and soil minerals. Phosphates move quickly through plants and animals. However, the processes that move phosphorus through the soil or oceans are very slow, making the phosphorus cycle, overall, one of the slowest bio-geochemical cycles. The global bio-geochemical phosphorus cycle (**FIGURE 12**) includes five major processes [Miller, 1998; Atlas & Bartha, 1987], *viz.*:

- ***Tectonic uplift***, leading to exposure of phosphorus-bearing rocks, such as apatite, to surface weathering;
- ***Geological cycling*** caused by physical erosion, and chemical and biological weathering of phosphorus-bearing rocks, enhanced by anthropogenic activities, such as mining, to expose dissolved and particulate phosphorus in soils and water resources;
- ***Cycling through terrestrial organisms***, causing sedimentation of particulate phosphorus (*e.g.,* phosphorus associated with organic matter and oxide/ carbonate minerals) and eventual burial in soils on land;
- ***Riverine and subsurface transportation*** of phosphorus to receiving lakes and runoff to the ocean; and

- ***Cycling through aquatic organisms*** to cause sedimentation of particulate phosphorus (*e.g.,* phosphorus associated with organic matter and oxide/ carbonate minerals) and eventually burial in the sediments in freshwater resources and the marine environment.

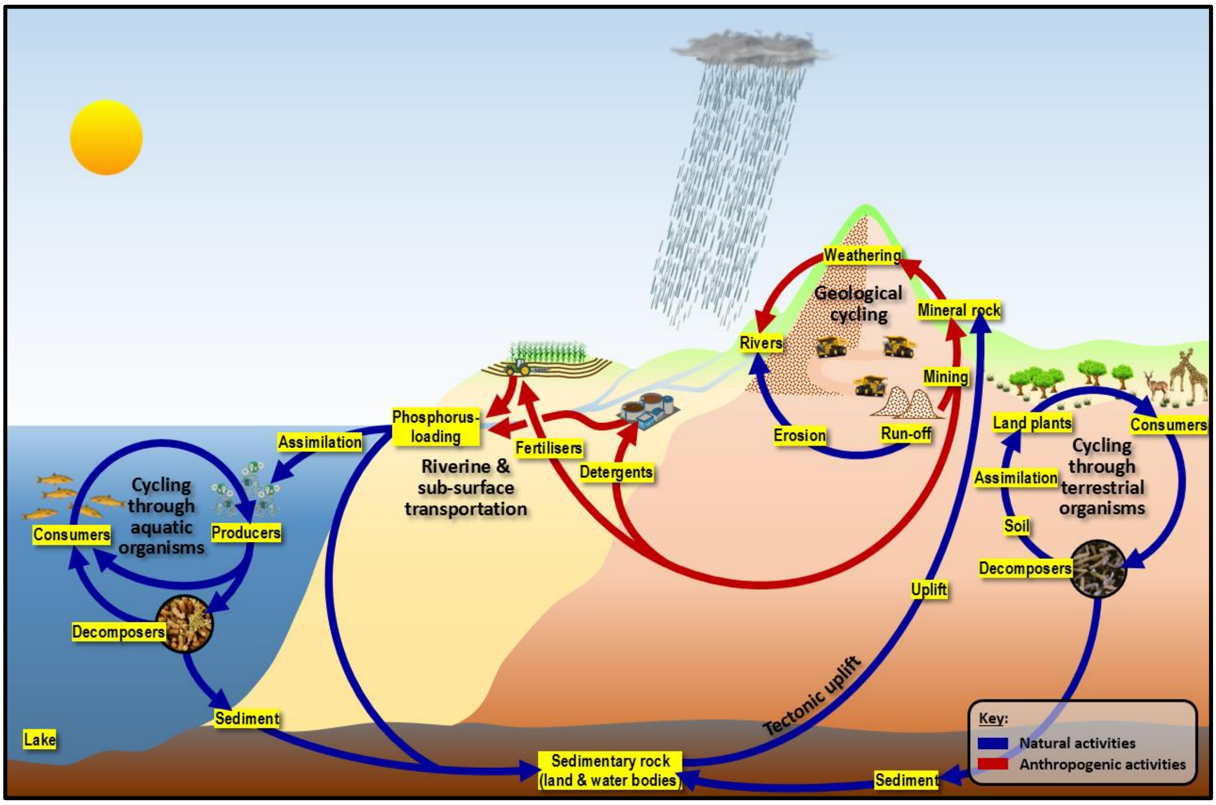

FIGURE 12: The bio-geochemical phosphorus cycle.

Elemental phosphorus is extremely reactive and does not occur in the natural environment. Phosphorus occurs in natural water as orthophosphates, polyphosphates, metaphosphates, pyrophosphates and organic phosphates, either dissolved or bound to particulate material. Of these, the orthophosphate species H_2PO_4 and HPO_4^{-2} are the only forms of soluble inorganic phosphorus that are directly utilizable by aquatic biota. Soluble Reactive Phosphorus (SRP), or orthophosphate (PO_4^{3-}) is generally considered to be the most immediately available form of phosphorus [DWAF, 1996; Walmsley, 2000]. In eutrophic lakes and under anaerobic conditions, there is a marked increase in soluble phosphorus (orthophosphate) content in the lower hypolimnion, since the oxidised microzone between the sediment and water phase is lost, with the resultant release of phosphate and ferrous iron into the water [Wetzel, 2001]. However, mineralisation[88]; adsorption onto suspended material or sediment; desorption under aerobic[2] conditions; assimilation by plants; and precipitation with calcium or iron, under aerobic conditions, to form relatively insoluble compounds that precipitate out of the water, are all processes that influence the concentration of available phosphorus in fresh and marine waters [Walmsley, 2000; Wetzel, 2001].

2.3.2 Nitrogen

Most of the Earth's atmosphere (±78%) consists of atmospheric nitrogen, making it the largest source of nitrogen. Nitrogen occurs in surface waters in several forms, *e.g.,* ammonium (NH_4^+), nitrite (NO_2^-), nitrate (NO_3^-), urea (CH_4N_2O), and diatomic nitrogen gas (N_2). All freshwater algae can assimilate the first four forms, but nitrogen gas can only be utilised by certain species of blue-green algae and bacteria (*e.g.,* cyanobacteria such as *Anabaena* species) [Brock & Madigan, 1988].

The nitrogen cycle is extremely important in determining the availability of nitrogen (timing and quantity) in surface waters [Walmsley, 2000]. Human activities, such as fossil fuel combustion, the use of artificial nitrogen fertilizers, and the release of nitrogen in wastewater have dramatically altered the global nitrogen cycle. Human modification of the global bio-geochemical nitrogen cycle can negatively impact on ecosystems and adversely affect human health.

The bio-geochemical nitrogen[93] cycle (**FIGURE 13**) incorporates processes by which nitrogen is converted into the other chemical forms, as it circulates among the atmosphere, terrestrial, and marine ecosystems.

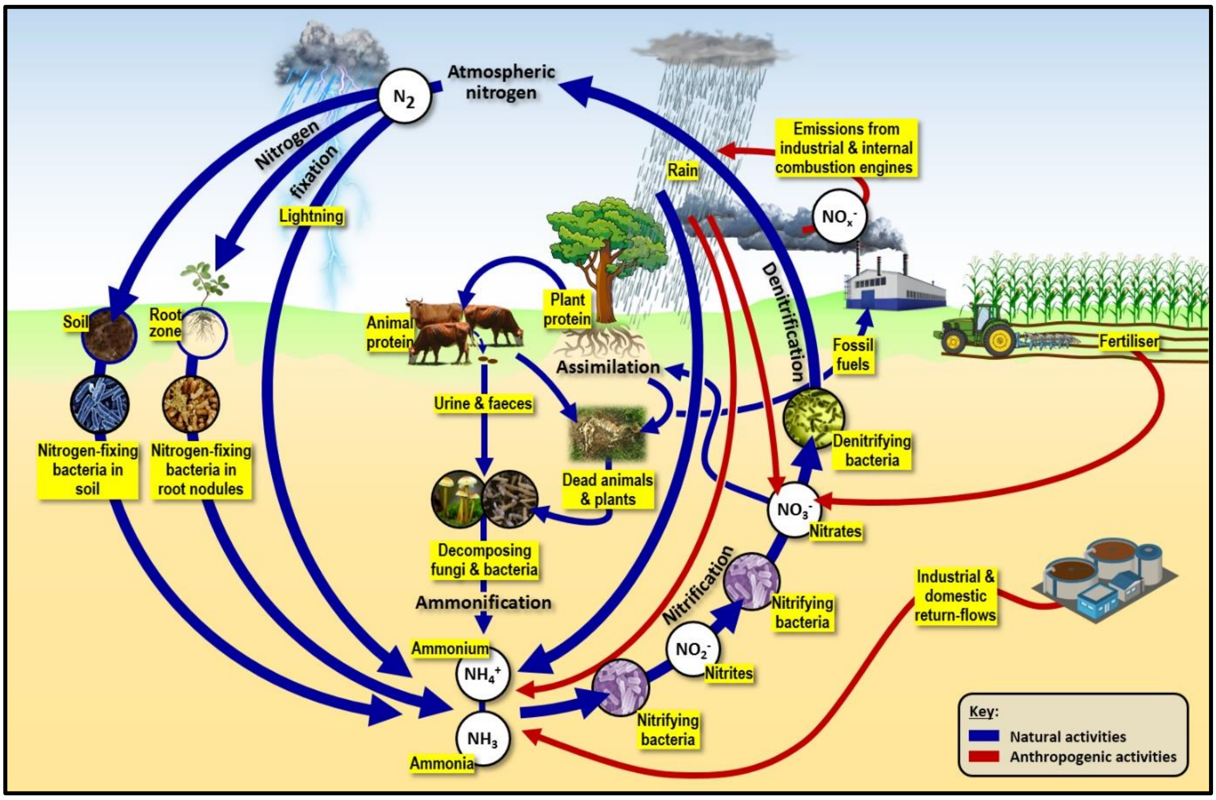

FIGURE 13: The bio-geochemical nitrogen cycle.

The bio-geochemical nitrogen cycle [Miller, 1998; Brock & Madigan, 1988; Atlas & Bartha, 1987; Davis, et al., 1980; Wetzel, 2001] includes:

- ***Nitrogen fixation***, which entails the conversion of nitrogen gas (N_2) into nitrites (NO_2^-) and nitrates (NO_3^-) through atmospheric, industrial and biological processes. Atmospheric nitrogen must be processed, or *"fixed"*, into a usable form before it can be assimilated by plants. A significant amount of nitrogen is fixed by lightning strikes, but most fixation is done by free-living or symbiotic bacteria known as diazotrophs[36] and certain heterocyst containing filamentous cyanobacteria;
- ***Assimilation***, by which plants absorb nitrates (NO_3^-) or ammonium (NH_4^+) from the soil or sediment through the cell walls of their root hairs. When nitrate (NO_3^-) is absorbed, it is first reduced to nitrite ions (NO_2^-) and then ammonium ions (NH_4^+) for incorporation into amino acids, nucleic acids, and chlorophyll. In some plants, nitrogen (N_2) can be assimilated in the form of ammonium ions (NH_4^+) directly from the root nodules[130];
- ***Ammonification*** or mineralisation, which takes place when a plant or animal dies, or when an animal expels waste, and bacteria or fungi convert the initial organic nitrogen within the remains back into ammonium (NH_4^+);
- ***Nitrification***, constituting the conversion of ammonium (NH_4^+) to nitrate (NO_3^-), which is performed primarily by soil-living and other nitrifying bacteria. In the primary stages of nitrification, the oxidation

of ammonium (NH_4^+) is performed by bacteria, such as the *Nitrosomonas* species, which convert free ammonia (NH_3) to nitrites (NO_2^-). Other bacterial species, such as *Nitrobacter*, are responsible for the oxidation of the nitrites (NO_2^-) into nitrates (NO_3^-). Under aerobic conditions certain cyanobacterial species (*e.g., Anabaena*, one of the filamentous species with heterocysts), in addition to the soil bacteria, which also occur in water resources, namely, *Azetobacter* and *Clostridium* can perform nitrification and convert N_2 in the epilimnion of impoundments to compounds that are readily available for uptake. It is important for the free ammonia (NH_3) to be converted to nitrites (NO_2^-) or nitrates (NO_3^-), because free ammonia (NH_3) gas is toxic to plants; and

- ***Denitrification***, by which nitrates (NO_3^-) are reduced back into nitrogen gas (N_2), which is inert and mostly unavailable to plants, completing the bio-geochemical nitrogen cycle. This process is performed by bacterial species, such as *Pseudomonas* and *Paracoccus*, under anaerobic conditions, *e.g.,* in waterlogged soils. These facultative anaerobic bacteria[60] can also live in aerobic conditions.

2.4 Phosphorus and nitrogen as limiting factors for biomass proliferation

The rate and extent of aquatic plant growth is dependent on the concentration and ratios of the nutrients present in the water. Plant growth is generally limited by the concentration of that nutrient that is present in the least quantities relative to the growth needs of the plant [Walmsley, 2000]. This is known as the Liebig's Law of the Minimum[77], or the *limiting nutrient concept*, and is the basis of the Eutrophication Management Strategy for South Africa.

The overall composition of aquatic plant tissue is C_{106}; H_{263}; O_{110}; N_{16}; and P, yielding a C:N:P w (weight):w:w ratio of 41:7:1. The ambient optimal N:P, w:w ratio for algal growth in surface waters is in the range of between 8:1 and 12:1. Because of nutrient supply and demand in nature, it has been observed that phosphorus and nitrogen are the most frequent limiting nutrients in freshwater systems. Increases in the levels of either of these two nutrients in a waterbody will raise the risk (extent and frequency) of experiencing eutrophication problems. Control of nitrogen and phosphorus inputs to the aquatic environment, therefore, is regarded as the key to the management of catchment eutrophication problems. Other nutrients can be important as limiting nutrients, but usually only under special circumstances [Walmsley, 2000].

In freshwater systems, phosphorus is normally limiting, whereas nitrogen is normally limiting in marine waters. This is mostly caused by centuries of phosphorus supply through surface runoff from land and the enhanced iron (Fe) sequestration by sulphide (S^{2-}) in high sulphate (SO_4^{2-}) containing marine waters, which reduces the availability of iron for phosphate (PO_4^{3-}) precipitation in marine waters, in comparison to freshwater systems. In the oxidative hydrolysis of iron and the concomitant precipitation of phosphate, a minimum of two iron (Fe) atoms are needed to precipitate one phosphate (PO_4^{3-}) molecule[89], *i.e.,* Fe:P=2. However, dissolved Fe:P<2 predominates in anoxic[5] marine waters, whereas most freshwater lakes show Fe: P>2, allowing almost complete phosphate sequestration on oxygenation in freshwater systems [Blomqvist, et al., 2004].

Stratification of water is a natural phenomenon in freshwater systems and the more saline environments. This is due to temperature or saline gradients that has different density properties. In freshwater it is primarily prevalent during summer periods due to temperature increases. In estuarine and coastal marine waters, it is particularly evident due to salinity or temperature gradients, when less dense freshwater from rivers meets heavier more dense seawater. Limited vertical mixing between these water layers restricts the supply of oxygen from surface waters to more saline bottom waters, leading to hypoxic conditions and the creation of *"dead zones"*. The formation of the *"dead zones"* is exacerbated by excessive nutrient-loading (particularly nitrogen loading as the limiting nutrient in seawater) and the consequential primary production that results in an accumulation of particulate organic matter, which encourages microbial activity and the further depletion of dissolved oxygen in hypolimnetic waters. Limiting nitrogen in effluents under such circumstances, thus, constitutes an important eutrophication management measure [Diaz & Rosenburg, 2008].

2.5 Measurement of phosphorus and nitrogen

To determine the levels of phosphorus and nitrogen in effluents, wash-off from land areas or in water resources, or for the purposes of determining compliance to Waste Discharge Standards[149] or in-water resource water quality objective [74], different parameters can be analysed and assessed.

The measurement of algal biomass, usually by means of analysing the Chlorophyll-α concentration in surface water resources – even though the percentage of Chlorophyll-α varies between species or during the lifecycle of a species, provides a direct indication of primary production and an indirect indication of the phosphorus (P) and nitrogen (N) levels in the water resources.

For the determination of phosphorus in wastewater and in water resources, Total Phosphorus (TP) and orthophosphate analysis are routinely performed [Pers. coms. Louw, 2022] for the following purposes (**TABLE 2**):

TABLE 2: Phosphorus determination in water and wastewater

PARAMETER	DESCRIPTION	PURPOSE
Total Phosphorus (TP)	All phosphorus (P) found in a water sample, whether dissolved or in the form of condensed phosphates.	Commonly analysed when sampling wastewater and water resources to indicate the total potentially available phosphorus.
Orthophosphate (PO_4^{3-})	Form of water-soluble P produced by natural processes or through human-influenced sources, like untreated sewage, and that is readily bioavailable.	Commonly analysed when sampling water resources to indicate the nutrient status of natural raw water.

For the determination of nitrogen in wastewater and in water resources, the most relevant substances are ammonium-nitrogen, organic-nitrogen, nitrate-nitrogen (NO_3^-) and nitrite-nitrogen (NO_2^-). Depending on the purpose, the following are analysed [Pers. coms. Louw, 2022] and/or assessed (**TABLE 3**):

TABLE 3: Nitrogen determination in water and wastewater

PARAMETER	DESCRIPTION	PURPOSE
Total Kjeldahl Nitrogen (TKN)	= Total Organic Nitrogen + Ammonium (NH_4^+)	Typically analysed when sampling wastewater that is associated with biological treatment processes.
Total Nitrogen (TN)	= TKN + Nitrate (NO_3^-) + Nitrite (NO_2^-)	Commonly analysed when sampling wastewater and water resources to indicate the total potentially available nitrogen.
Total Organic Nitrogen (TON)	= TKN – NH_4^+	Organic nitrogen is generally of concern more as Biological Oxygen Demand (BOD) than as a source of nitrogen.
Total ammonia	= NH_3 + NH_4^+	Provides an indication of the aerobic and anaerobic decomposition of organic material.
Free un-ionized ammonia (NH_3)	= Total ammonia – NH_4^+	Provides an indication of ammonia toxicity (which is pH and temperature dependant) that for instance affects the aquatic ecology.
Dissolved Inorganic Nitrogen (DIN)	= (NO_3^- + NO_2^-) + NH_3	Commonly analysed when sampling water resources to indicate the nutrient status of raw water.

2.6 The trophic status of waterbodies

Trophic status refers to the degree of nutrient enrichment[100] in surface water resources and the amount of primary productivity[116] that can be sustained. Important to note; is that the trophic status of water resources is affected by multiple abiotic, biotic, physico-chemical[109] and biological factors (**FIGURE 14**) that impact on the nutrient concentrations within the water resource. Natural factors [Carlson & Simpson, 1996] that influence the trophic status of waterbodies, include:

- **Atmospheric precipitation**, such as rainfall, hail, snow, etc., containing soluble nutrients (predominantly nitrates) that promotes primary production;
- The properties of the **geology and the soils**, and the extent of essential nutrient(s) mobilisation, which contribute to high natural background levels of phosphorus and nitrogen from mineral sources, and the promotion of primary production;
- **Geohydrological and hydropedological characteristics** that enable and assist with nutrient transport through the soil profile to promote primary production;
- **Hydrology** that causes either the flushing or the concentration of nutrients in aquatic ecosystems, with well-flushed systems, generally, tolerating higher nutrient inputs;
- **Residence time and hydraulics** that affect cell growth and primary production;
- **Ecological infrastructure**, such as wetlands, which provide natural attenuation and water quality improvement functions;
- **Water chemistry**, primarily the concentrations of the limiting nutrients – phosphorus or nitrogen – that affect primary production;
- The **remobilisation of nutrients** from the bottom sediments into the water columns of rivers and reservoirs, which often exacerbates and/or prolongs eutrophication problems. The release rates from sediments for phosphorus and nitrogen, however, differ;
- The availability of **sunlight** that affects plant growth. An abundance of sunlight supports primary production;
- Inorganic **turbidity**, which reduces **water clarity and light penetration** all affect the amount of available light for plant growth. Turbid systems can tolerate higher levels of nutrients;
- Changing **temperature** regimes, which can affect stratification[139] of the water column and algal growth patterns;
- **Seasonal variation** that causes the responses of algae and aquatic macrophytes to available nutrients to vary according to the time of the year;
- The **morphology of the waterbody**, which influences the impacts of eutrophication through both depth and shape. Deep waterbodies can tolerate higher inputs of nutrients; and
- **Primary production**.

Interestingly, whereas turbidity affects the penetration of sunlight, turbidity does not necessarily affect total algal growth [Robarts & Zohary, 1992]. Robarts and Zohary (1984) demonstrated that the Hartbeespoort Dam's euphotic zone[56] becomes compressed under turbid conditions, *i.e.* reduces from what in a clear water reservoir would have been 6.4 m to 0.6 m, but with primary production remaining at levels consistent with the nutrient status of the particular waterbody.

The presence of nutrients constitutes a common factor that plays a role in most of the natural influences on eutrophication discussed above. This phenomenon supports the management of anthropogenic eutrophication's focus on those two nutrients that are limiting to primary production in water resources and that play a key role in causing anthropogenic eutrophication.

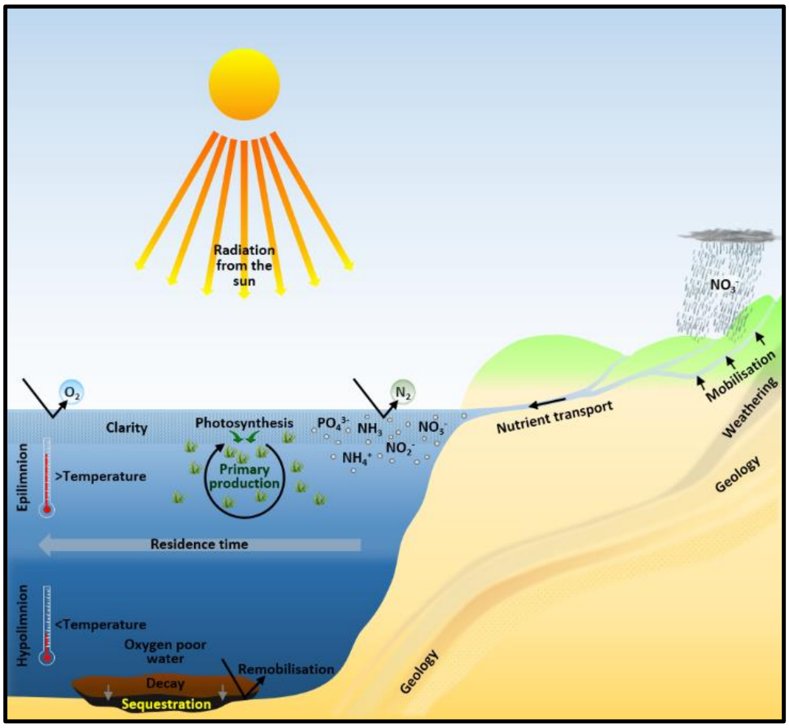

FIGURE 14: Natural factors that affect the trophic status of water resources.

The causes and effects of eutrophication are very complex and vary somewhat for different aquatic systems. However, there are some general trends in lakes becoming eutrophic. The relationships among phosphorus input; primary production, usually phytoplankton biomass[15]; density of benthos[13]; submerged macrophytes[80]; dissolved hypolimnetic[70] oxygen[39]; biological diversity; and trophic status are shown conceptually in **FIGURE 15**.

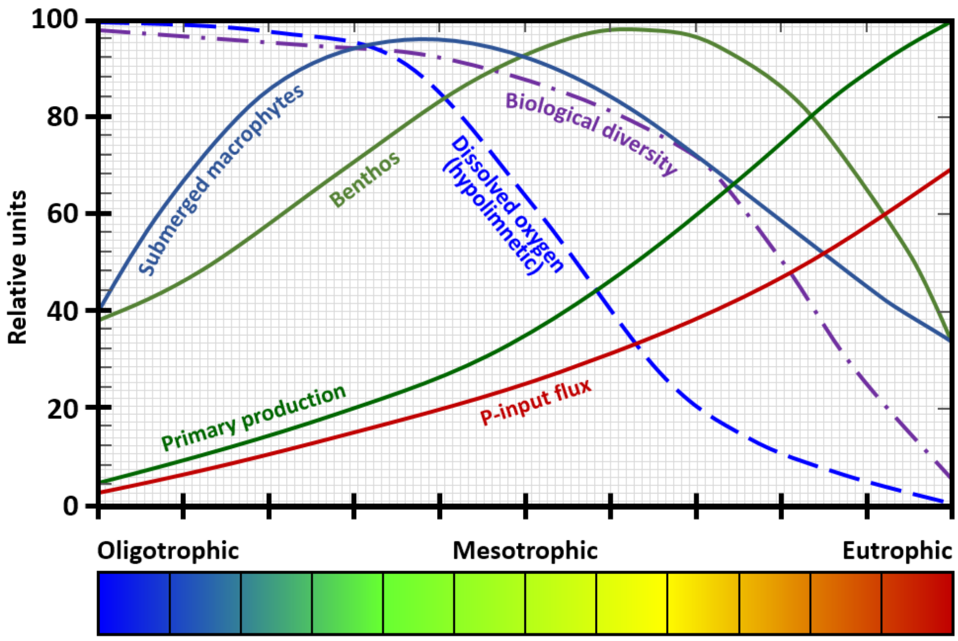

FIGURE 15: Conceptualisation of freshwater eutrophication [Adapted from Roos, 2009 and Correll 1998].

The observation, that the trophic status of water resources is affected by multiple abiotic, biotic, physico-chemical and biological factors, highlights the importance of adapting eutrophication management to the conditions in individual ecosystems.

A Trophic State Index (TSI) is a classification system designed to rate waterbodies based on the amount of biological productivity they sustain. Although the term *"trophic index"* is commonly applied to lakes, any surface waterbody may be indexed. Trophic classification makes it possible to describe waterbodies in terms of the primary production continuum, to predict system behaviour, to judge fitness-for-use and to assign perceived utility [Fosberg & Ryding, 1980].

Unfortunately, the biological structure of most waterbodies does not respond in a linear fashion to nutrient additions. For instance, algal biomass is usually concentrated in the benthos of fast-flowing, gravel or cobble bed streams (*i.e.* periphyton[106] dominated) and measured as benthic Chl-α per unit area of stream substrate, whereas in slow-moving, sediment-depositing rivers and lakes (*i.e.*, plankton[111] dominated), algal biomass is suspended in the water column and measured as sestonic[134] Chl-α per unit water volume [EPA, 2000a, p. 26].

Toerien, *et al* (1975) noted the importance of classifying South Africa's water resources according to their trophic status for eutrophication management purposes. Carlson (1977), followed by Fosberg & Ryding (1980), Walmsley (2000) and endorsed by [DWAF, 2002], proposed the following definitions to describe the degrees of nutrient enrichment and the primary production that it can sustain:

- ***Oligotrophic*** means the presence of low levels of nutrients, the least amount of biological productivity and *"good"* water quality;
- ***Mesotrophic*** means intermediate levels of nutrients, moderate levels of biological productivity and *"fair"* water quality;
- ***Eutrophic*** means high levels of nutrients, high levels of biological productivity and *"poor"* water quality; and
- ***Hypertrophic*** means excessive levels of nutrients, excessive levels of biological productivity, plant production being governed mostly by physical factors and water qualities ranging between *"poor"* and *"unacceptable"*. The water quality problems in hypertrophic waterbodies are almost continuous.

Vollenweider and Kerekes (1980) used a statistical approach to quantify probability ranges for several variables within each trophic designation to produce bell-shaped curves per trophic class for each variable. The overlap that resulted emphasized that waterbodies of the same concentrations may be in more than one trophic class [EPA, 2000b]. **FIGURE 16** depicts the primary production continuum for total phosphorus (TP) in lakes [OECD, 1982].

Although probabilistic curves are handy to typify waterbodies in terms of the relationships of selected parameters and trophic status, its usefulness, as basis for the development of a general TSI, is limited because of the number of parameters that must be measured and the assumption that specific waterbody types exist [Carlson & Simpson, 1996]. **TABLE 4** lists examples of key physical, chemical and biological parameters and their expected changes in response to increasing eutrophication. Initially, biological activity is expected to increase as eutrophication increases. This will be the case up to a point where increasing biological stress is likely to be incurred as eutrophication continues to increase.

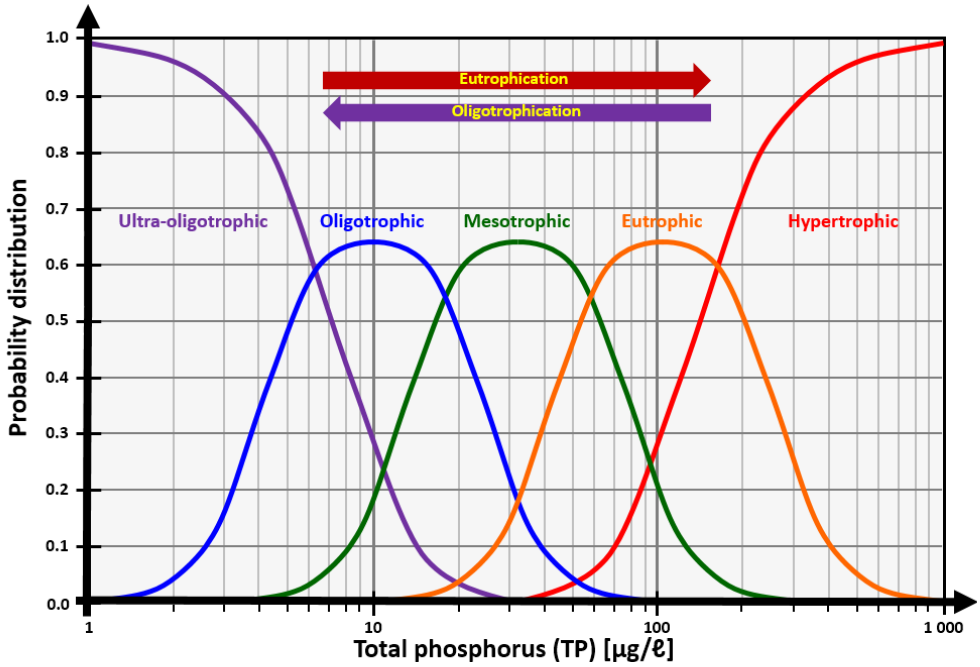

FIGURE 16: The primary production continuum [adapted from OECD, 1982].

TABLE 4: Trophic criteria and their responses to increased eutrophication[9] [Rast, et al., 1989].

PHYSICAL	CHEMICAL	BIOLOGICAL [10]
Transparency (Secchi transparency[132]) ↓	Nutrient concentrations ↑	Algal bloom frequency ↑
Suspended Solids ↑	Chlorophyll-α[23] ↑	Algal species diversity ↓
Electrical conductivity (EC) ↑	Dissolved solids ↑	Phytoplankton biomass ↑
	Hypolimnetic[70] oxygen deficit ↑	Littoral vegetation [11] ↑
	Epilimnetic[55] oxygen supersaturation ↑	Zooplankton[162] ↑
		Fish [12] ↑
		Bottom fauna [13] ↑
		Bottom fauna diversity ↓
		Primary production ↑

Multi-parameter indices are onerous, and the linear relationship assumed between the parameters in some of these indices does not hold [Carlson, 1977]. On the other hand, indices based on a single criterion potentially could be both unambiguous and sensitive to change. However, there is currently no consensus as to what the single criterion of trophic status should be, and it is doubtful that an index based on a single

[9] ↑ signifies that the value of the parameter generally increases with the degree of eutrophication; whereas ↓ signifies that the value generally decreases with the degree of eutrophication.

[10] Biological criteria have important qualitative (*e.g.,* species) changes as well as quantitative (*e.g.,* biomass) changes, as the degree of eutrophication increases.

[11] Aquatic plants in shallow, nearshore areas may decrease in the presence of high densities of phytoplankton.

[12] May be decreased in numbers and species in bottom waters (hypolimnion) beyond a certain degree of eutrophication, because of hypolimnetic oxygen depletion, *i.e.* the initial increase may be reversed under hypertrophic conditions.

[13] Bottom fauna may be decreased in numbers and species in high concentrations of hydrogen sulphide (H_2S), methane (CH_4) or carbon dioxide (CO_2), or low concentrations of oxygen (O_2) in hypolimnetic waters.

parameter would be widely accepted. The ideal TSI should incorporate the best of both approaches, retaining the expression of the diverse aspects of trophic state found in multi-parameter indices, yet still having the simplicity of a single parameter index. This can be done if the commonly used trophic criteria are interrelated.

Carlson (1977) developed such an index (TSI) that is both simple, in terms of the limited number of parameters being considered, as well as being appreciative of the multi-dimensional nature of the *"trophic status"* concept, by considering the interrelatedness of the selected parameters and other factors that influence biological activity. According to Carlson (1977), waterbodies are rated on a scale from zero to one hundred. Each major division (10, 20, 30, etc.) represents a doubling in algal biomass. The index number can be calculated from any of several parameters, including Secchi disk transparency,[14] and chlorophyll-α, and total phosphorus concentrations (**TABLE 5**). The TSI can be a valuable tool in the management of surface water resources, but it is also a valid scientific tool for investigations where an objective for trophic state is necessary.

TABLE 5: Trophic State Index (TSI) and associated parameters for waterbodies [Carlson, 1977, p. 365; Carlson & Simpson, 1996].

TROPHIC STATE INDEX (TSI)	SECCHI DISK [m]	TP [µg/ℓ]	CHL-A [µg/ℓ]	Trophic Class
0	64	0.75	0.04	*"Oligotrophic"*
10	32	1.5	0.12	
20	16	3	0.34	
30	8	6	0.94	
40	4	12	2.6	*"Mesotrophic"*
50	2	24	6.4	*"Eutrophic"*
60	1	48	20	
70	0.5	96	56	*"Hypertrophic"*
80	0.25	192	154	
90	0.12	384	427	
100	0.062	768	1183	

The trophic state of waterbodies affects its use or perceived utility (**FIGURE 17**).

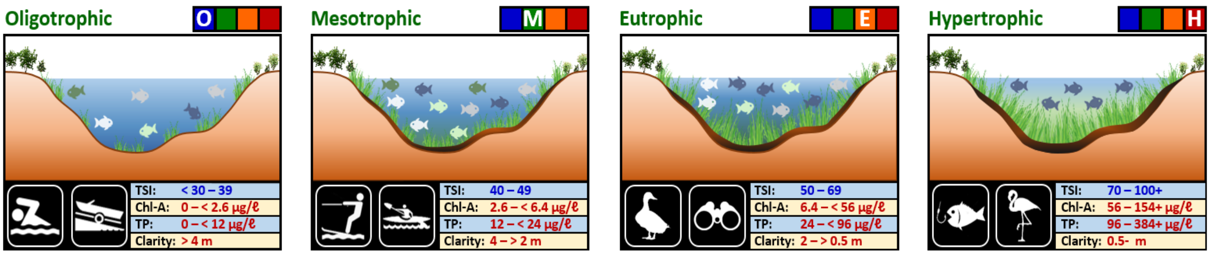

FIGURE 17: The trophic state of waterbodies affects their use and perceived utility [adapted from Fosberg & Ryding, 1980 and Carlson, 1977].

TSI = Trophic State Index; Chl-α = Chlorophyll-α; TP = Total Phosphorus; Clarity = Secchi Depth
O = Oligotrophic; M = Mesotrophic; E = Eutrophic; H = Hypertrophic

[14] Parameters, such as clarity and transparency, should be used with circumspect in cases where dissolved organic compounds (*e.g.*, tannins) or suspended solids are present in significant amounts, as such results may be misleading — giving the impression that the waterbody is more biologically productive than it actually is.

TABLE 6 summarises the perceived utility of waterbodies residing in different trophic classes:

TABLE 6: Trophic classes and their associated perceived utility [Fosberg & Ryding, 1980].

TROPHIC STATE INDEX (TSI) *	UTILITY OF THE WATERBODY
< 30	Such waterbodies are good for water sports and good sources for drinking water. These waterbodies exhibit clear water with good visibility, but may potentially not provide the necessary nutrients and algae to maintain a healthy environment for fish and wildlife.
between 30 to 45	Such waterbodies have an adequate amount of nutrients, which supports a fair number of algae, aquatic plants, birds, fish, insects and other wildlife.
between 46 to 70	Such waterbodies have a greater amount of nutrients, which can support an abundance of algae, aquatic plants, birds, fish, insects and other wildlife.
between 71 to 100	Such waterbodies have the highest levels of nutrients, and have the potential to support the highest levels of biological productivity (*e.g.*, an abundance of algae, aquatic plants, birds, fish, insects, and other wildlife.) These waterbodies, however, have the greatest potential for widely ranging dissolved oxygen conditions, which can have a detrimental effect on biological diversity, and natural plants and animals.

* As per the TSI set out in **TABLE 5**.

Van Ginkel, et al (2000b) uses the criteria, noted in **TABLE 7**, for the concentrations of phosphorus (as total phosphorus); and planktonic algae and cyanobacteria (as chlorophyll-α), to classify the trophic status of impoundments in South Africa [DWAF, 2002]:

TABLE 7: South African classification of trophic status according to total phosphorus (TP) and chlorophyll-α (Chl-α) concentrations in lakes [DWAF, 2002].

VARIABLE	UNIT	OLIGOTROPHIC	MESOTROPHIC	EUTROPHIC	HYPERTROPHIC
Mean annual Chl-α	µg/ℓ	0 < **Chl-α** ≤ 10	10 < **Chl-α** ≤ 20	20 < **Chl-α** ≤ 30	**Chl-α** > 30
% of time Chl-α > 30 µg/ℓ	%	**%Chl-α** = 0	0 < **%Chl-α** ≤ 8	8 < **%Chl-α** ≤ 50	**%Chl-α** > 50
Mean annual TP	mg/ℓ	**TP** ≤ 0.015	0.015 < **TP** ≤ 0.047	0.047 < **TP** ≤ 0.130	**TP** > 0.130

Applying the above trophic status classification criteria (**TABLE 7**) to 393 South African impoundments, 37.7% of the reservoirs were classified as hypertrophic; 28.2% as eutrophic; 21.9% as mesotrophic[84]; and 12.2% as oligotrophic[103], for the 2019/2020 hydrological year (**FIGURE 18)**. Additionally, **FIGURE 18** shows a consistent deterioration in the trophic status of these impoundments for the 2019/2020 hydrological year, compared to the 2016/2017 hydrological year [Data obtained from NIWIS, 2021].

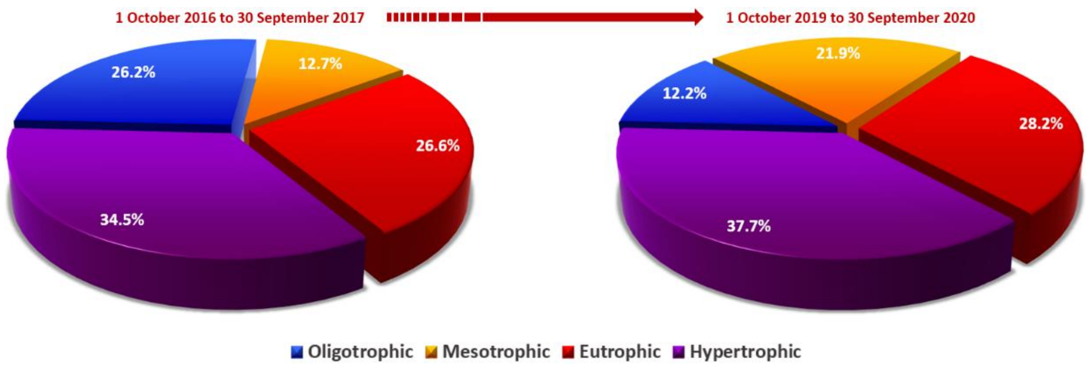

FIGURE 18: Comparison of the trophic status of 393 South African impoundments for the 2016/2017 and 2019/2020 hydrological years.

This TSI (**TABLE 7**), which was developed for National Eutrophication Monitoring Programme (NEMP), was established for impoundments. The application thereof to rivers and streams must be done with circumspection, as it will have to be adapted prior to applying the TSI to such water resources. TSIs for rivers and streams may be available internationally, but will have to be adapted to South African conditions, with the aridity of the country in mind.

2.7 The role of the catchment

It is often said: *"A waterbody is a reflection of its catchment!"* [Holdren, et al., 2001].

A river or a lake is not an isolated body of water, but part of a larger system which includes the surrounding land that drains into such waterbodies. The geographical area from which rain and surface water drain toward a common receiving water resource is called a basin[11], drainage region[40], watershed[161], or catchment[21]. In addition to the natural factors affecting the trophic status of waterbodies (mentioned in **Section 2.6**, Part 1), anthropogenic activities within a waterbody's catchment have a significant effect on the amount of nutrients that enter the waterbody and, therefore, the primary productivity [EPA, 2000b]. This constitutes the primary reason why appropriate nutrient standards and objectives are required to control human activity and to manage eutrophication in catchments.

A natural waterbody's nutrient concentration is affected, primarily, by the nutrient content of precipitation, the rate of weathering of geologic formations and the dissolution of natural minerals from soils in the catchment. If the underlying geology is mostly granitic, then the rates of weathering will be slow and both the productivity of the terrestrial vegetation and the concentration of nutrients in the runoff from the catchment will be low. On the other hand, if the underlying bedrock is sedimentary, the weathering rates will be higher and the fertility of the soil and the nutrient content of the runoff water will be higher, as well [EPA, 2000b].

Human activity has at least three effects on the nutrient load input into waterbodies:

- It disturbs the overlying vegetation, exposing the soil to increased weathering and erosion [EPA, 2000b];
- It adds easily erodible nutrient-containing material, such as fertilizers, and human and animal waste, into the catchment [EPA, 2000b]; and
- It increases the area of impervious surfaces and compacts soils making them less pervious and leading to increased runoff that acts as conveyance mechanism for sediments and nutrients. In high rainfall areas, transport can be *"supply-limited"* (little or no material is available to be transported) and in low rainfall areas, the transport can be *"transport-limited"* (the water volume or runoff is insufficient to result in the transport of available materials) [Pers. coms. Thornton, 2021].

As the biological surface of an undisturbed catchment is disrupted or converted to impervious surfaces, and as people move into the catchment, it can, thus, be expected that there will be increased soil and nutrient runoff. Of course, the degree of disturbance relative to the size of the waterbody will affect the impact of the disturbance; building a summer cottage would not have the same impact on a lake as would clear-cutting of natural vegetation or dense urban development. Sometimes the term *"assimilative capacity"*[8] is used to imply that the waterbody has a certain capacity to absorb the impact of disturbance. In a eutrophication context, this concept, although comforting, probably has little basis in fact. Impact, until demonstrated otherwise, is probably better thought of as a continuous response to nutrient increases (**FIGURE 19**). The degree of change will depend on other factors, for example the size of the waterbody or any of the other factors mentioned in **Section 2.6**, and the change may not immediately or even ever be detectable to humans or their monitoring instruments. However, whether detected or not, changes do occur. It is for this reason that catchment disturbance is a sensitive early warning of waterbody change. Clearly, biological impact within the waterbody will be directly related to the increased amount of nutrient-loading, and that impact will occur, whether or not it is detected [EPA, 2000b].

Prevailing weather conditions in catchments also affect nutrient regimes and eutrophication in streams, rivers and impoundments. Additionally, South African impoundments, even in the hypolimnetic layer, seldom reach temperatures below 9°C. The potential for bacterial activity increases significantly at temperatures exceeding 10°C and increases exponentially with every 1°C increase above 10°C. This can have a serious impact on the anaerobic conditions, especially in hypertrophic impoundments, where anaerobic areas push through the thermocline and thus recycle nutrients to the epilimnetic waters during summer algal and cyanobacterial blooms [Pers. coms. Van Ginkel, 2022].

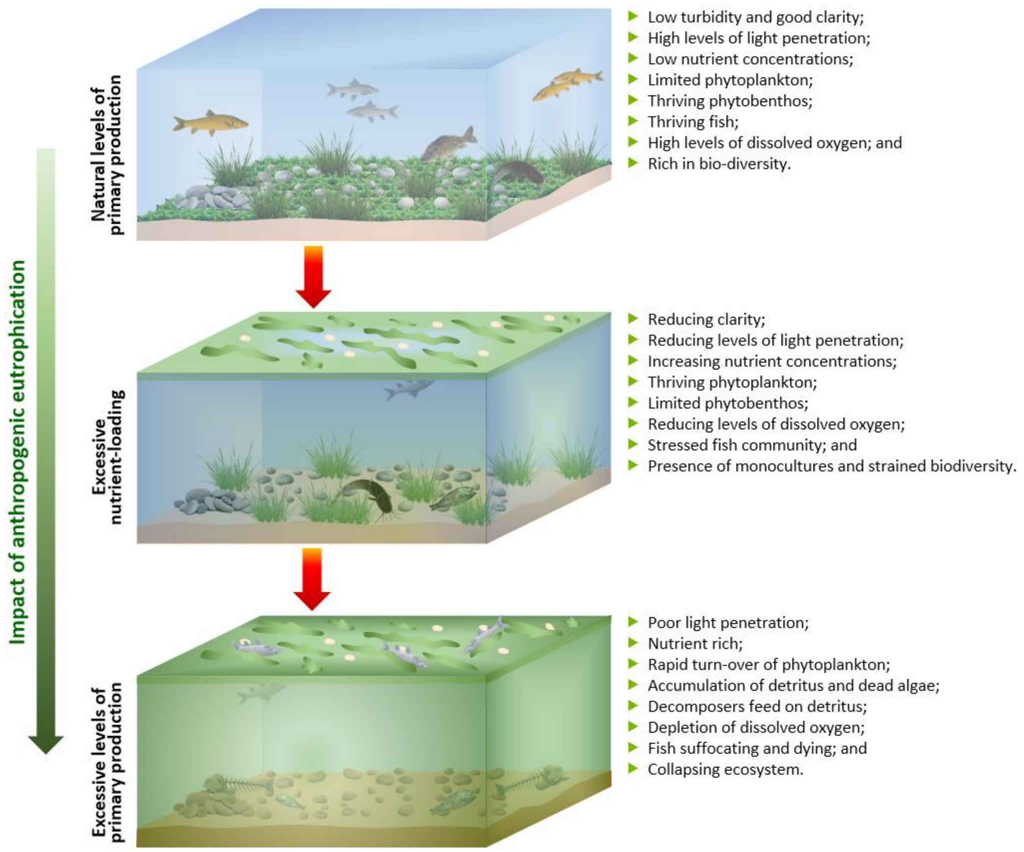

FIGURE 19: The effects of eutrophication on aquatic ecology and biological diversity.

Human population growth and associated economic activities are the main driving forces behind eutrophication problems. Humans use numerous products and resources which contain phosphorus and nitrogen[93], converting them into elemental compounds[28] (or, available phosphorus and nitrogen) and ultimately releasing them through various pathways into the aquatic environment [Walmsley, 2000]. **FIGURE 20** illustrates the linkages between human activity and eutrophication.

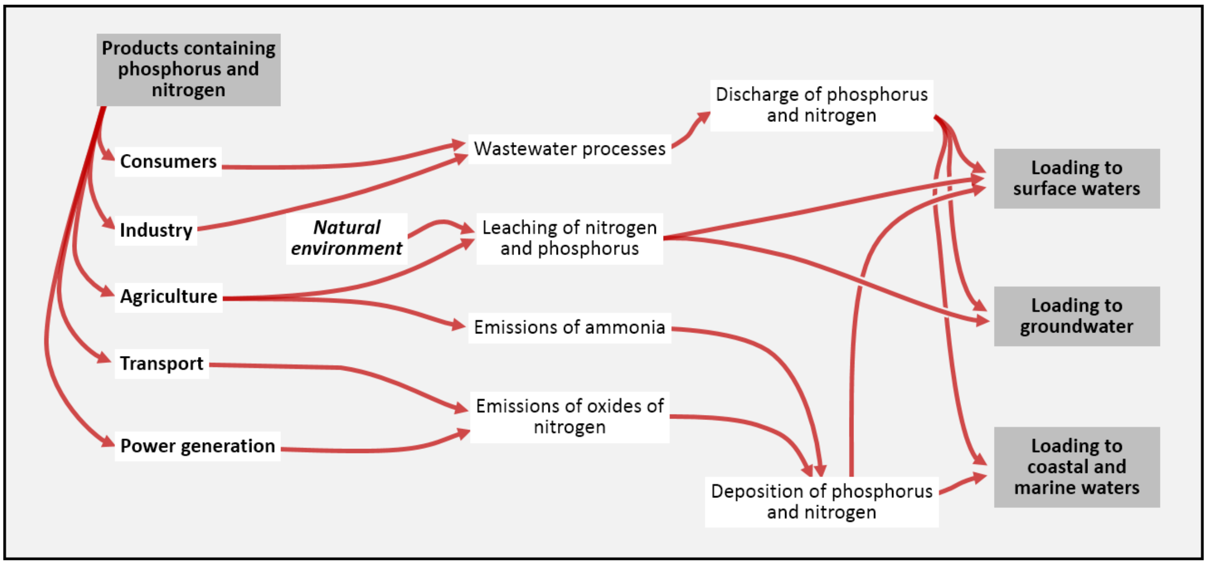

FIGURE 20: The routes by which nutrients from various sources enter waterbodies [Walmsley, 2000].

There are two main ways in which nutrients are introduced to the aquatic environment, *viz.* point[112] and diffuse[38] (non-point)[38] sources of nutrients (**FIGURE 21**):

- **Point sources** of pollution are directly discharged to receiving water resources at discrete locations, such as through pipes and ditches from WwTWs, industrial sites and confined intensive livestock operations. The most severe water quality impacts from point source pollution typically occur during the summer or dry periods, when river flows are low and the capacity for dilution is reduced, as well as during storm events, when uncontrolled sewer overflows occur more frequently; and
- **Diffuse sources** of pollution are indirectly discharged to receiving surface water and groundwater resources, via surface flow, subsurface flow (leaching) and atmospheric deposition during periods of rainfall and irrigation. Soil properties, such as the soil pH, and iron, aluminium and calcium contents, affect the mobility of nutrients, such as phosphorus, through soils. The most severe water quality impacts from diffuse source pollution occur during storm periods, particularly after a dry spell, when rainfall induces hillslope hydrological processes and runoff of pollutants from the land surface [Reese, 2020].

Models are useful when engaging in forward planning and comparing scenarios on a catchment basis with the aim of pro-actively recommending and implementing appropriate management interventions and timeously preventing and addressing the effects of eutrophication. Nutrients, unlike salts and other conservative pollutants[29], however, act in a non-conservative[94] manner (**FIGURE 22**). This is due to nutrients, such as phosphorus and nitrogen[93], changing concentration naturally. Some react chemically to result in different salts. Sometimes oxygen is taken out of the water to release hydrogen gas, which is more volatile and escapes. Oxygen content, be it depletion or overabundance, in water is the cause of many changes. For example, ammonia is oxidized to nitrites, which in turn are oxidized to nitrates. The nitrates cannot be eliminated, except by chemical replacement, absorption or biochemically, as is now done in some wastewater treatment processes. Simple mass balance modelling, therefore, is mostly not readily possible.

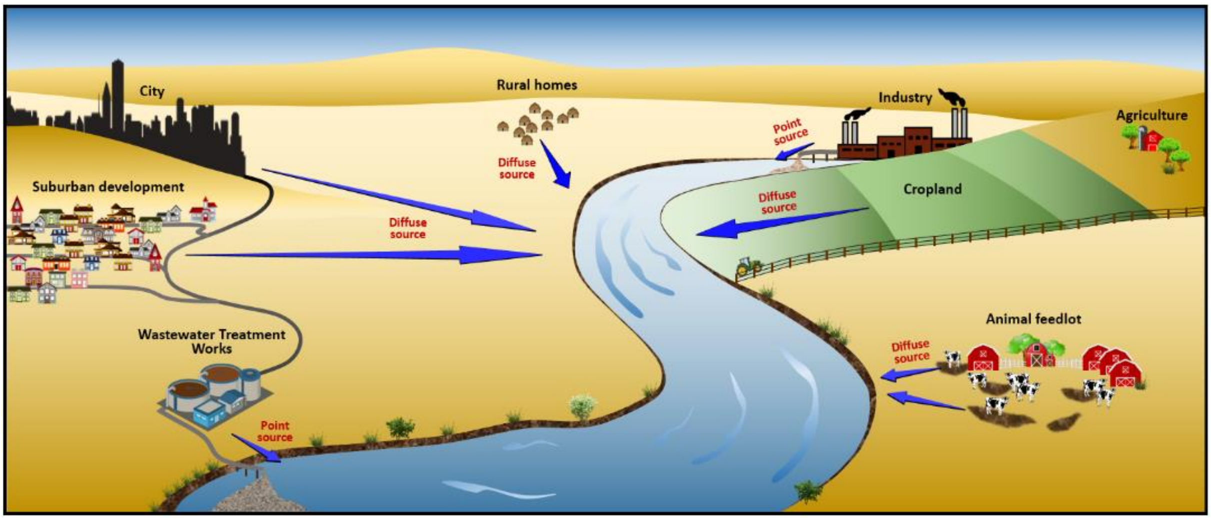

FIGURE 21: Point and diffuse sources of nutrients in a catchment context [Rossouw & Forster, 2008].

The term *"mass balance modelling"* comes from the assumption that a substance, such as phosphorus, cannot just appear or disappear from a reservoir; it must come from somewhere and it must go somewhere. The phosphorus going into the reservoir must either go out again through some outflow, be sedimented to the bottom, incorporated into biomass, or remain in the waterbody in either dissolved or particulate forms. It is this phosphorus that remains in the water that is of interest because it is the amount that is available for primary production.

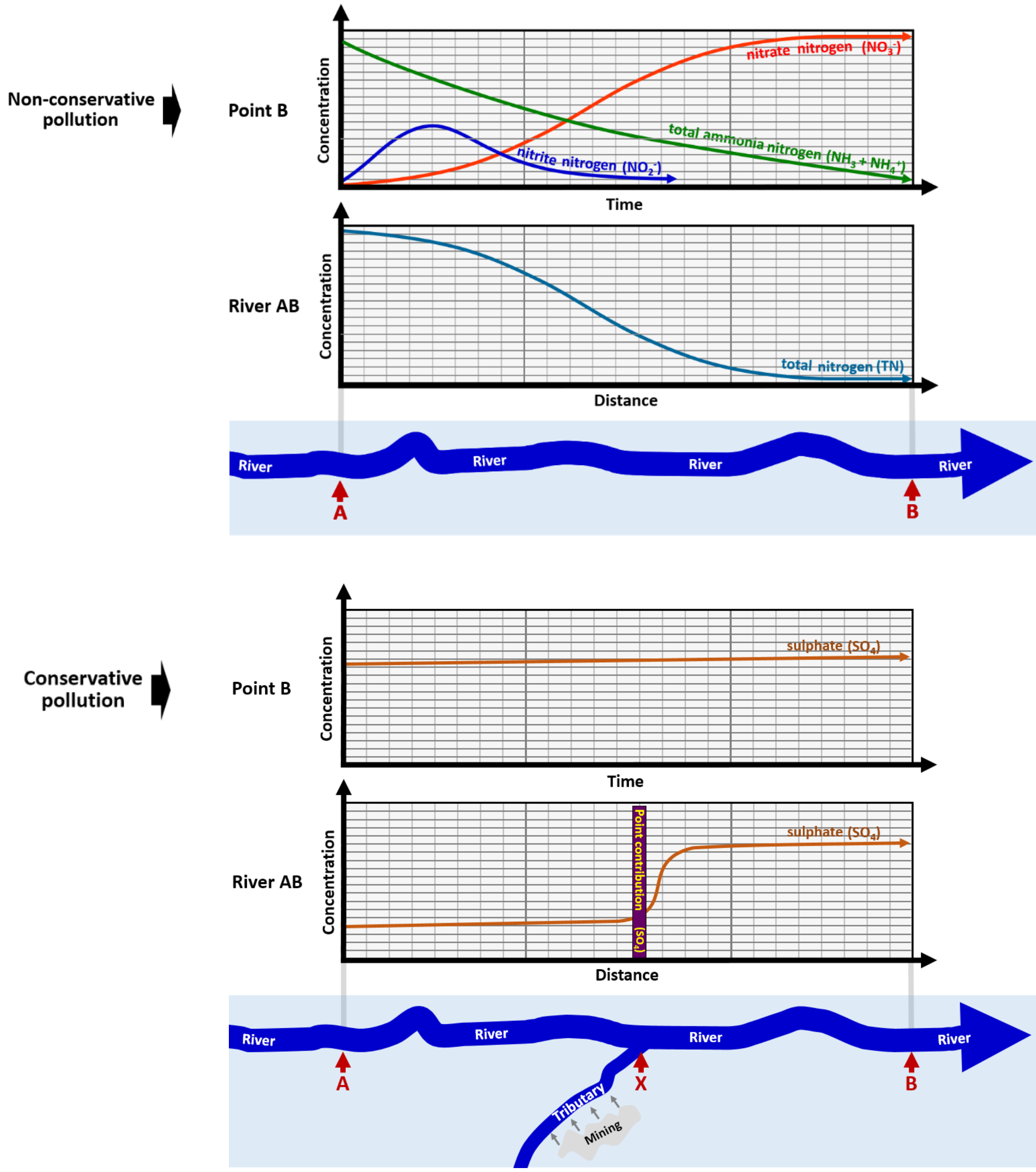

FIGURE 22: A theoretical comparison between non-conservative and conservative water pollution, comparing nitrogen and sulphate trends on *concentration-over-time*, and *concentration-over-distance* graphs.

Thornton, et al. (2013) outline eutrophication as a complex or *"wicked problem"* (**Annexure B**) facing society, which cannot simply be fixed with only engineering solutions, such as the application of suitable wastewater treatment technologies. By adopting a blanket approach to eutrophication management, the characteristics of this complex problem would be ignored. To be more explanatory, complex problems, like eutrophication, can have multiple resolutions, depending on a variety of factors [Thornton, et al., 2013], and a national approach to eutrophication management must include catchment and focused water resource planning with local action.

CHAPTER 3: TOWARDS A EUTROPHICATION MANAGEMENT STRATEGY FOR SOUTH AFRICA

3.1 Purpose of the eutrophication management strategy document

To date, eutrophication in South Africa, has been dealt with under the broad guidance of the overarching Integrated Water Quality Management Policy and Strategy for South Africa, 2017 [DWS, 2017b; DWS, 2017d] and the other general policies for water quality management and pollution control before it [DWAF, 1991]. Due to deteriorating water quality trends being observed in recent years, specifically worsening occurrences of eutrophication, the need has been identified to develop the first dedicated policy and strategy for a particular water pollution type, *viz.* to explicitly and decisively address the escalating effects of excessive nutrient enrichment observed in many hot-spot areas in the country.

To this end, the purpose of the eutrophication management strategy document is:

(1) To **give direction** with respect to the management of eutrophication, in particular the control of anthropogenic sources of excessive nutrient enrichment, from a strategic country-wide perspective;

(2) To **provide a reference** for the control of triggers that cause excessive primary production in receiving water resources and for eutrophication management, in general, in South Africa;

(3) To **provide the foundation for operational consistency** at the Water Management Area (WMA), sub-catchment and local levels, by stipulating ground rules and prescribing overarching implementation approaches for the management of eutrophication;

(4) To address pertinent issues of the **integration and alignment** of eutrophication management with other processes;

(5) To facilitate improved eutrophication management through **cooperation and participation**;

(6) To provide the **basis for identifying priority actions and interventions** necessary to control significant triggers of anthropogenic eutrophication and their root causes of failure, acknowledging the need for the efficient and wise utilisation of scarce resources;

(7) To facilitate **capacity building** in respect of the control of the causes of excessive nutrient enrichment and eutrophication management; and

(8) To provide a point of departure for the **monitoring and evaluation** of eutrophication management strategy implementation progress.

3.2 Scope of the eutrophication management strategy

The general practice of utilising **policy** to define ground rules, to delineate intent and to specify desired outcomes, coupled with a **strategy** to map out overarching implementation approaches to realise the said policy objectives, is also applicable here. In addition to the **eutrophication management policy** that seeks to review and express the South African government's policy objectives with respect to eutrophication management and nutrient reduction, the **eutrophication management strategy** pursues concomitant approaches to implement the objectives of the eutrophication management policy over time.

As such, the *Eutrophication Management Strategy for South Africa* must–

- **apply nationally** (*i.e.*, to the country as a whole);
- address issues of **anthropogenic nutrient-loading** (*i.e.,* predominantly phosphorus and nitrogen-related), which might have the following adverse effects (if left unattended):
    - Lead to excessive nutrient enrichment in water resources (*i.e.* surface and/or groundwater resources);

- Impair the resource quality of the country's water resources;
- Give rise to water quality and nuisance concerns (thus negatively affecting property value, impairing fitness-for-use and restricting potential utility);
- Cause eutrophication of surface water resources, and eventually the marine environment;
- Risk ecologically sustainable development; and
- Ultimately, have undesirable social and economic consequences.

The management measures in the *Eutrophication Management Strategy for South Africa*–

- focus on the regulation and **control** of land-based anthropogenic **sources of nutrient-loading**;
- set out resource water quality planning and management measures to balance the needs for water use with the needs to **protect water resources**; and
- **outline remedial measures** (for both water resource focused remedial measures or focussing on the remediation of nutrient pollution sources of impacts) that must be implemented reactively, in order to control nutrient-loading.

The *Eutrophication Management Strategy for South Africa*, furthermore, provides an outline for the management of anthropogenic eutrophication at the following scales:

- **source-specific**;
- **local**;
- **sub-catchment**, up to **Water Management Area** (WMA);
- **national**; and
- **trans-boundary** and **international**.

The Strategy should ideally be complemented with a water resource planning programme that schedules the development and implementation of water resource system and/or sub-catchment strategies. This is essential to accommodate differing and changing catchment and local dynamics expected to unfold over time when evaluating, selecting and prioritising suitable operational intervention options for roll-out in eutrophication *"hotspot"* areas. Additionally, day-to-day eutrophication management related water resource and services activities will have to be executed in accordance with the policy and strategy outline provided in this document.

Whilst the DWS is the custodian of the country's water resources, the *Eutrophication Management Strategy for South Africa* is directed at all three spheres of government (*i.e.,* local, provincial and national government). Furthermore, in support of the integrated management of eutrophication, management collaboration between different role-players is required, including between shared watercourse institutions, non-governmental organisations, the private sector, the research community and civil society. Although it is acknowledged that South Africa's surface water runoff affects our coastal marine waters, the management of marine eutrophication *per se* is excluded from the current scope. This document is aimed at all that have a role to play in South Africa's socio-economic growth and development, that impact on, or that are impacted by eutrophication of water resources[158], or that have a stake in the country's future.

The DWS is gradually adapting its water resource management approach to review and develop policy and strategy (where lacking), to convert policy and strategy into action (where in existence) and progressively shift to planning more strategically, providing overall regulatory oversight; institutional support; coordination in aid of enhanced co-operative governance; and improved regulatory control. This changing emphasis aims for greater involvement of water services and management institutions, and other role-players, within the water sector.

3.3 Anatomy of the eutrophication management strategy document

The document consists of five consecutive parts. Parts 1 to 4 (**FIGURE 23**) contain the technical narrative, whereas Part 5 (not depicted in **FIGURE 23**) contains the bibliography. Collectively, these individual parts of the document strive to help the reader to comprehend the measures necessary to manage eutrophication country-wide, and ultimately to control and to reduce eutrophication in hot-spot areas.

Part 1 starts off with a focused discussion to highlight key eutrophication-related challenges in South Africa, followed by a broad problem declaration that takes the form of an analysis of eutrophication-related causes and effects in South Africa. The introduction to Part 1, also, defines several important concepts pertaining to the subject of eutrophication. An ensuing discussion, on the strategy document and its development, sheds light on the scope, purpose, anatomy and the development process of the *Eutrophication Management Strategy for South Africa*. This is followed by focused discussions on relevant international commitments and key policy and legislative provisions that give guidance to eutrophication management in South Africa. Part 1 concludes with an assessment of the evolution of eutrophication measures in South Africa, thereby extrapolating the past and current eutrophication management paradigms and trends to an enhanced paradigm for the future management and control of eutrophication in South Africa.

Part 2 builds the broad context sketched in Part 1 into an overall policy vision and solution orientated policy statements for eutrophication management in South Africa.

Part 3 focusses on advancing the eutrophication management policy, as elaborated under Part 2, in order to prepare the way for full implementation. Core, functional and supporting strategies for eutrophication management in South Africa are discussed and are related to achieving the overall policy vision, given in Chapter 2, Part 2. Governance requirements are explored with the aim of identifying governance responsibility and accountability.

Part 4 pursues short, medium and long-term implementation imperatives and ends with concluding remarks.

FIGURE 23: The anatomy of the *Eutrophication Management Strategy for South Africa* document.

3.4 Eutrophication management strategy development process and stakeholder involvement

An iterative four phase process (**FIGURE 24**), supported by consultation at multiple levels, was adopted to develop the *Eutrophication Management Strategy for South Africa*. This process commenced with an inception phase that was used to define a final and mutually agreed description of the scope of work, project programme and project resource requirements to effect efficient and structured project execution. The Inception Phase was followed by Phase 2, which consisted of a high-level literature review; an identification and evaluation of the emerging causes, effects and challenges associated with eutrophication; and a data and information gap analysis that was accompanied by the formulation of measures to overcome such identified gaps. Utilising the information base put together during the Situation Assessment and Gap Analysis Phase, Phase 3 set out to develop a *Eutrophication Management Strategy for South Africa*. The development approach followed during Phase 3 culminated in two editions of the policy and strategy document; a first edition that was presented to various groups of stakeholders and the final edition that was produced after the various consultative exercises. The project concluded with Phase 4, which had as its goal the investigation of measures and production of a plan to ensure policy and strategy roll-out and implementation.

Due to the important roles of the public and private sectors, as well as civil society, in eutrophication management, a Stakeholder Consultation and Communication Strategy was developed to inform; consult; involve; collaborate with; and, where possible, empower relevant key role-players to take part in the development of the *Eutrophication Management Strategy for South Africa*. Additionally, the Stakeholder Consultation and Communication Strategy had to establish ownership of, and buy-in to both project process and outcomes, and information sharing had to take place throughout the project duration to ensure robust debate and scientific rigour (**FIGURE 25**). A database of stakeholders consulted, and a comments register was maintained and has been compiled.

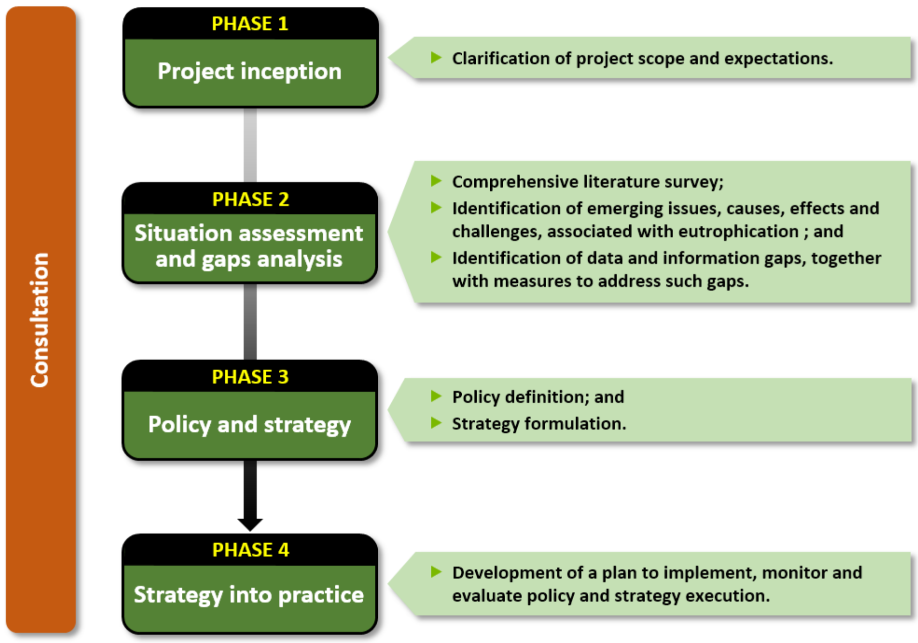

FIGURE 24: *Eutrophication Management Strategy for South Africa* development process.

The abbreviated terms of reference of the various components of the project structure that oversaw the policy and strategy development process were as follows:

- ***Project Steering Committee (PSC):*** Responsible for indicating overall direction and sanctioning of all project deliverables prior to departmental endorsement;
- ***Project Management Committee (PMC):*** Responsible for project management tasks;
- ***Technical Task Team with Sub-Task Teams:*** Responsible for thematic specialist support; and
- ***External stakeholder group/ public:*** Responsible for wider stakeholder input and public participation.

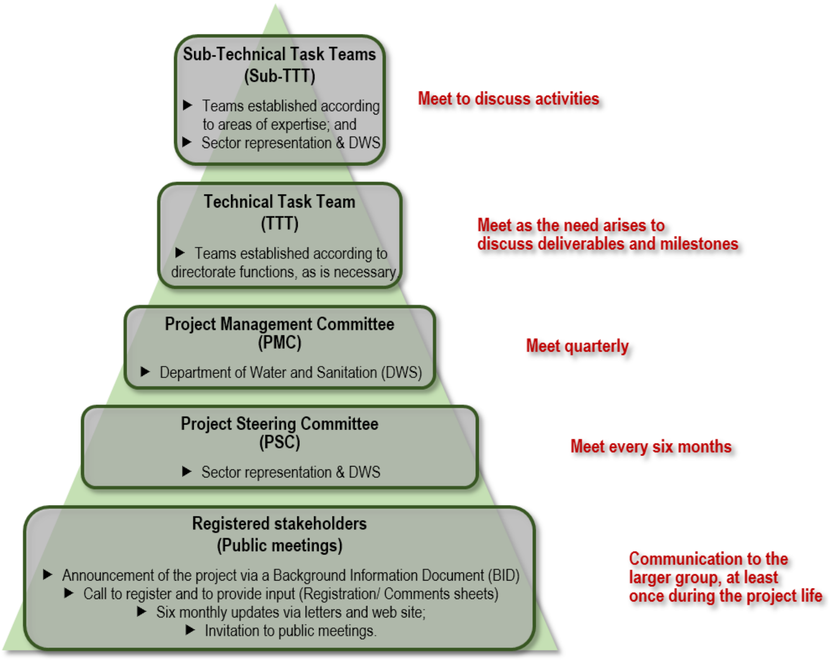

FIGURE 25: Stakeholder consultation.

CHAPTER 4: POLICY, STRATEGY AND LAW CONTEXT

The purpose of the ensuing discussion is to highlight the most prominent policy, strategy and legislative elements, deemed to be giving direction to eutrophication management, and to highlight some important aspects with which to align eutrophication management. To this end, linkages are pursued with the international sustainable development agenda; key pieces of national legislation, with respect to applicable law principles; selected executive strategies; and the Integrated Water Quality Management Policy and Strategy for South Africa (2017).

4.1 The international sustainable development agenda

The concept of sustainable development formed the basis of the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992. The summit marked the first international attempt to draw up action plans and strategies for moving towards a more sustainable pattern of development. Agenda 21 was one of the key outputs of UNCED and Chapter 18 of this agenda identifies freshwater resources as an essential component of the Earth's hydrosphere and as an indispensable part of all terrestrial ecosystems [UNCED, 1992].

Sustainable development was the solution to the problems of environmental degradation discussed by the Brundtland Commission in their preceding 1987 report – Our Common Future [Brundtland, 1987]. According to Brundtland (1987), *"sustainable development"* is: ***"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"***. This interpretation of sustainable development has been adopted in the Bill of Rights in the Constitution of democratic South Africa and forms a central theme in all our environmental legislation and policy.

The Natural Step Framework, colloquially known as The Natural Step (TNS) Funnel (**FIGURE 26**), provides a conceptual model for easy reference and discussion of the concepts of sustainable- and unsustainable development. The TNS Funnel is based on four system conditions, also known as the principles of sustainability (**TABLE 8**), to be met if sustainability is to be reached and maintained [Nathan, 2018].

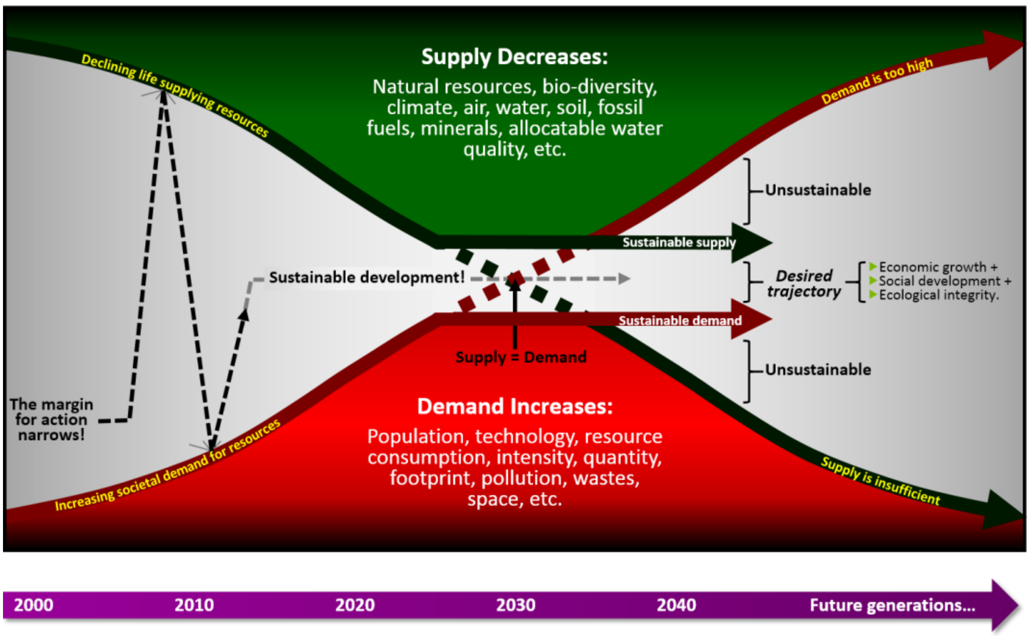

FIGURE 26: Natural Step Funnel demonstrating converging global supply and demand [Adapted from Robért, 2008].

TABLE 8: The four principles of sustainability [Robèrt, 2008], related to eutrophication.

IN A SUSTAINABLE SOCIETY –	
Principle 1	*nature is not subjected to systematically increasing concentrations of substances extracted from the Earth's crust;*
	Explanation: Ecosystem functions and processes are altered when society mines and disperses materials at a faster rate than they are being redeposited back into the Earth's crust. (Examples of these materials are phosphorus, coal, and metals, such as lead.)
Principle 2	*nature is not subjected to systematically increasing concentrations of substances produced by society;*
	Explanation: Ecosystem functions and processes are altered when society produces substances faster than they can be broken down by natural processes, if they can be broken down at all (for example, a build-up of nutrients in the environment causing eutrophication).
Principle 3	*nature is not subjected to systematically increasing degradation by physical means; and*
	Explanation: Ecosystem functions and processes are altered when society extracts resources at a faster rate than they are replenished (for example, overharvesting trees or fish), or by other forms of ecosystem manipulation (for example, causing soil erosion or paving over fertile land).
Principle 4	*human needs are being met worldwide.*
	Explanation: By considering the first three principles of sustainability, within which human life-supporting structures and functions are being altered, three basic principles for maintaining essential ecological processes have been defined. Principle 4 recognizes that social and economic dynamics fundamentally drive the actions that lead to ecosystem changes. Principle 4, therefore, focuses on the socio-economic dimension in terms of the importance of meeting human needs worldwide as an integral and essential part of sustainability.

In September 2000, the historic Millennium Declaration, in which countries committed to achieving a set of eight measurable goals, called the Millennium Development Goals (MDGs), which included halving the population that had no sustainable access to water and basic sanitation before 2015 (Target 7c), were signed into action [UN, 2015a]. The World Summit on Sustainable Development (WSSD) was held in Johannesburg in 2002 to assess progress since the initial Rio Summit. The Johannesburg Summit delivered three key outcomes: a political declaration, the Johannesburg Plan of Implementation, and a range of partnership initiatives. Key commitments included those on sustainable consumption and production, water and sanitation, and energy [WSSD, 2002]. The Rio^{+20} conference (UNCED) in Rio de Janeiro, June 2012, subsequently galvanized a process to develop a new set of 17 Sustainable Development Goals (SDGs) to carry on the momentum generated by the MDGs, beyond 2015, and fit into a global development framework, called Agenda 2030 [UN, 2015b].

The SDG programme, endorsed by Heads of State (including by South Africa), serves as a reporting platform to measure the sustainability of countries; to prompt action in cases where poor performance or where deteriorating trends emerge; to bolster local accountability; and for global comparison purposes. SDG 6 focuses on clean water and sanitation, and must ensure availability and sustainable management of water and sanitation for all. SDG 6 was unpacked into six SDG targets and 2 additional supporting SDG targets. Of these, the following four SDG Targets specifically relate to eutrophication management (**TABLE 9)**. A series of twelve indicators, some global, some domesticated and other additional indicators,[15] were proposed to collectively measure progress against the said four SDG targets:

[15] The annotation: *"D"* for *"Domestic"* and *"A"* for *"Additional"*, as per UN convention, is used to identify the indicators in **TABLE 9**. In cases where neither *"D"* nor *"A"* is denoted, the global indicator wording was retained, as proposed by the UN, and has been adopted without change for South Africa.

TABLE 9: SDG 6 targets and indicators, with direct relevance to eutrophication management.

SDG 6:	**Ensure availability and sustainable management of water and sanitation for all.**
SDG TARGET 6.2:	**SANITATION AND HYGIENE**
By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.	
Indicator 6.2.1:	Proportion of population using safely managed sanitation services, including a handwashing facility with soap and water.
SDG TARGET 6.3:	**WATER QUALITY AND WASTEWATER**
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.	
Indicator 6.3.1D:	Proportion of water containing waste lawfully discharged.
Indicator 6.3.2D:	Proportion of bodies of water that complies with water quality objectives.
Indicator 6.3.3A:	Proportion of water containing waste recycled or reused.
Indicator 6.3.4A:	Proportion of waste lawfully disposed of.
Indicator 6.3.5A:	Proportion of waste recycled or reused.
SDG TARGET 6.5:	**WATER RESOURCES MANAGEMENT**
By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.	
Indicator 6.5.1:	Degree of integrated water resources management implementation (0 - 100).
Indicator 6.5.2:	Proportion of transboundary basin area with an operational arrangement for water cooperation.
SDG TARGET 6.6:	**WATER-RELATED ECOSYSTEMS**
By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.	
Indicator 6.6.1D(1):	Change in the spatial extent of water-related ecosystems over time, including wetlands, reservoirs, lakes and estuaries as a percentage of total land area.
Indicator 6.6.1D(2):	Number of systems affected by high trophic and turbidity states.
Indicator 6.6.1D(3):	Change in the national discharge of rivers and estuaries over time.
Indicator 6.6.1A(1):	Change in the ecological condition of rivers, estuaries, lakes and wetlands.

Importantly, it has been observed that water pollution affects each of the other 16 SDGs, underscoring the inter-relatedness and importance of water resources that are fit for use in sustainable development. Enhanced synergy between the SDG programme, specifically the SDG targets and indicators summarised in **TABLE 9**, and the management of eutrophication must be encouraged – particularly in relation to the following:

- Reporting on the safe management of faecal waste along the entire sanitation chain, from containment to final treatment and disposal;
- Reporting on compliance to phosphorus and nitrogen Waste Discharge Standards (WDSs);
- Reporting on the fitness-for-use of water resources, with respect to phosphorus and nitrogen loading;
- Reporting on the application of wastewater recycling and reuse strategies;
- Reporting on the degree of integration of water resource management efforts; and
- Reporting on the status of ecological systems affected by phosphorus and nitrogen loading.

4.2 Key pieces of national legislation

4.2.1 Constitution of the Republic of South Africa, 1996 (Act No. 108 of 1996)

The Bill of Rights contained in the Constitution (108:1996) applies to all law, and binds the legislature, the executive, the judiciary and all organs of state.

Section 24 (**TABLE 10**) in the Bill of Rights places a duty on the state to implement reasonable legislative and other measures in order to protect water resources, and to ensure that they are not harmful to anyone's health and wellbeing. *"Other measures"*, in this case, include the roll-out and implementation of eutrophication management strategy to protect water resources and to ensure that they are not harmful to anyone's health and well-being.

TABLE 10: Constitution of the Republic of South Africa, 1996 (Act No. 108 of 1996): Bill of Rights: Implications for water resources

ENVIRONMENT	WATER RESOURCES
Section 24 addresses the *"environment"* [51] in its broad context, considering the ecology, social and economic dimensions.	**Section 24 paraphrased to address the *"freshwater environment"*, as a subset of the *"environment"*[51], considering the ecology, social and economic dimensions.**
Everyone has the right-	**Everyone has the right-**
(a) to an environment that is not harmful to their health or well-being and	**(a)** to water resources that are not harmful to their health or well-being and
(b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that-	**(b)** to have water resources protected, for the benefit of present and future generations, through reasonable legislative and other measures that-
(i) prevent pollution and ecological degradation;	**(i)** prevent pollution and ecological degradation;
(ii) promote conservation; and	**(ii)** conserve water; and
(iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.	**(iii)** secure ecologically sustainable development and use of water resources while promoting justifiable economic and social development.

Additionally, Section 27 in the Bill of Rights places a duty on the state to take reasonable legislative and other measures, within its available resources, to achieve the progressive realisation of providing sufficient water to everyone. The right to basic sanitation is not an explicit constitutional right. However, the right to sanitation could be derived from the right to a clean environment (Section 24), read together with the right of access to clean water (Section 27). Again, it is inferred that *"other measures"* include the roll-out and implementation of a eutrophication management strategy to ensure fitness-for-use of receiving water resources, *inter alia* through effective sanitation services.

Many other constitutional rights in the Bill of Rights overlap with, and support the rights to clean water resources, and water supply and sanitation services. These include the rights to equality (Section 9), dignity (Section 10), access to information (Section 32) and just administrative action (Section 33) [Algotsson, et al., 2009, p. 2].

Rolling-out and implementing the Eutrophication Management Strategy for South Africa, certainly, should promote these constitutional rights. It must protect water resources against the effects of eutrophication, thereby contributing towards securing ecologically sustainable development and use of water resources while promoting justifiable economic and social development.

4.2.2 National Environmental Management Act, 1998 (Act No. 107 of 1998)

According to Glazewski (2005), environmental law encompasses the following three distinct but interrelated areas of general concern:

- Land-use planning and development;
- Resource conservation and utilisation; and
- Waste management and pollution control.

Overseeing these three areas affects eutrophication[58] management. The National Environmental Management Act, 1998 (Act No. 107 of 1998)[16] is a framework Act and, therefore, provides for overarching mechanisms, principles and procedures which inform other acts, particularly the Specific Environmental Management Acts (SEMAs) of which the National Water Act, 1998 (Act No. 36 of 19198) is part, and subordinate or subsidiary regulations. Additionally, the statutory mechanisms, principles and procedures so established by NEMA (107:1998) would also apply to subsequent environmental policy and strategy being established, including the Eutrophication Management Strategy for South Africa.

NEMA (107:1998) defines *"sustainable development"* as *"the integration of social, economic and environmental factors into planning, implementation and decision-making so as to ensure that development serves present and future generations"*. NEMA (107:1998), further, provides that sustainable development requires the consideration of all relevant factors including-

- that the **disturbance of ecosystems and loss of biological diversity** are avoided, or, where they cannot be altogether avoided, are minimised and remedied;
- that **pollution and degradation** of the environment are avoided, or, where they cannot be altogether avoided, are minimised and remedied;
- that the **disturbance of landscapes and sites** that constitute the nation's cultural heritage is avoided, or where it cannot be altogether avoided, is minimised and remedied;
- that **waste** is avoided, or where it cannot be altogether avoided, minimised and re-used or recycled where possible and otherwise disposed of in a responsible manner;
- that the **use and exploitation of non-renewable natural resources** is responsible and equitable, and considers the consequences of the depletion of the resource;
- that the **development, use and exploitation of renewable resources** and the ecosystems of which they are part do not exceed the levels beyond which their integrity is jeopardised;
- that a **risk-averse and cautious approach** is applied, which considers the limits of current knowledge about the consequences of decisions and actions; and
- that **negative impacts** on the environment and on people's environmental rights be **anticipated and prevented**, and where they cannot be altogether prevented, are minimised and remedied.

NEMA (107:1998), further, sets out a number of supporting national environmental management principles, also having relevance to eutrophication management. These principles serve as guidelines which any organ of state must apply in any function, or when taking any decision, concerning the protection of the environment (see **Annexure C**).

In addition, NEMA (107:1998) calls for *"co-operative environmental governance"*; a phrase derived from the constitutional mandate [RSA, 1996, Chapter 3] that all spheres and organs of government are obliged to co-ordinate their actions by establishing principles to be considered in all decision-making processes affecting the environment.

NEMA (107:1998) plays a crucial role in providing for co-operative environmental governance by-

- establishing principles for decision-making on matters affecting the environment; and

[16] Hereafter referred to as NEMA (107:1998).

- establishing institutions that will promote co-operative governance and procedures for co-ordinating environmental functions exercised by organs of state.

Key environmental regulatory authorities include:

- Department of Agriculture, Land Reform and Rural Development (DALRRD);
- Department of Forestry, Fisheries and the Environment (DFFE);
- Department of Mineral Resources and Energy (DMRE); and
- Department of Water and Sanitation (DWS).

All spheres of government and all organs of state must co-operate, consult and support one another on matters involving or affecting the environment, including matters relating to eutrophication. Co-operative environmental governance must promote the right to an environment that is not harmful and may not be used as a mechanism to evade accountability.[17]

4.2.3 National Water Act, 1998 (Act No. 36 of 1998) and Water Services Act, 1997 (Act No.108 of 1997)

The National Water Act, 1998 (Act No. 36 of 1998),[18] together with the Water Services Act, 1997 (Act No. 108 of 1997),[19] promotes sustainability and equity, as central guiding principle in dealing with water resources and services. The NWA (36:1998) deals with the protection, use, development, conservation, management and control of water resources and is focused, *inter alia,* on promoting efficient, sustainable and beneficial use of water in the public interest; facilitating social and economic development; protecting aquatic and associated ecosystems and their biological diversity; and reducing and preventing pollution and degradation of water resources, whereas the WSA (108:1997) contains provision for basic water supply and sanitation services.

Water law in South Africa is based on *28 fundamental principles and objectives*, as approved by Cabinet in November 1996 [DWAF, 1997]. Eutrophication management policy and strategy should thus conform to these fundamental principles and objectives, especially the *13 principles and objectives* that are of foremost relevance to the management of eutrophication (**Annexure D**). Accordingly, eutrophication management policy and strategy must[20]–

- acknowledge that eutrophication management is nested within the broader concept of catchment management ***[links to Principle 5 and finds expression in the NWA (36:1998) inter alia in Chapter 2]***;
- strive to contribute towards long-term ecologically sustainable social and economic development ***[links to Principles 7 and 9 and finds expression in the NWA (36:1998) inter alia in Chapters 3 and 4]***;
- contribute towards water resource use, development, management and control that is in the public interest, sustainable, equitable and efficient, while also honouring relevant international obligations ***[links to Principle 13 and finds expression in the NWA (36:1998) inter alia in Chapter 2 and 4]***;
- where desirable, promote wastewater reuse and recycling ***[links to principle 14 and finds expression in the NWA (36:1998) inter alia in Chapter 4]***;
- acknowledge interrelatedness between eutrophication and water quantity, *i.e.,* water flow, level and pattern ***[links to Principle 15 and finds expression in the NWA (36:1998) inter alia in Sections 13]***;

[17] Refer to **POLICY STATEMENT 11**: Eutrophication management responsibility and accountability.

[18] Hereafter referred to as the NWA (36:1998).

[19] Hereafter referred to as the WSA (108:1997).

[20] A consolidated summary of the 13 principles and objectives, regarded as most relevant to eutrophication management policy and strategy, as listed in **Annexure D**.

- employ financial incentive systems, such as the Waste Discharge Charge System (WDCS), to limit and prevent excessive primary production in receiving water resources ***[links to Principle 16 and finds expression in the NWA (36:1998) inter alia in Chapter 5]***;
- consider land use management and management cooperation, as a means of limiting and preventing anthropogenic eutrophication ***[links to Principle 18 and finds expression in the NWA (36:1998) inter alia in Sections 12 and 26(1)(g)]***;
- promote effective water use authorisation ***[links to Principle 19 and finds expression in the NWA (36:1998) inter alia in Chapter 4]***;
- acknowledge the roles of disaster management in limiting danger to life and property ***[links to Principle 21 and finds expression in the NWA (36:1998) inter alia in Chapter 14]***;
- enable role-players and other stakeholders to participate ***[links to Principle 23 and finds expression throughout the NWA (36:1998)]***; and
- ensure that water services are provided in a manner consistent with the goals of water resource management ***[links to Principles 25 and 27 and finds expression in the NWA (36:1998) inter alia in Chapter 2 and in the WSA (108:1997) inter alia in Chapter 3]***.

The water law provisions, as paired above with the implications of the *13 fundamental principles and objectives* that are most relevant to eutrophication management, are further contextualised in **Section 5.2.1** of Part 1, specifically also in **Annexure E**.

4.3 Selected executive strategies, plans or frameworks

4.3.1 National Water Resource Strategy and National Water and Sanitation Master Plan

The National Water Resources Strategy (NWRS) is a statutory strategy, required in terms of the NWA (36:1998), is binding on all authorities and institutions implementing the Act and provides the framework for integrated water resource management for the country as a whole, and also within which water resources will be managed at the regional or catchment level. The National Water and Sanitation Master Plan (NW&S MP) constitutes the roll-out mechanism for NWRS implementation and specifies, *inter alia,* priority budget items, scheduled up to 2030 and beyond, for the entire water sector [DWS, 2018c]. Collectively, the NWRS and NW&S MP is the primary mechanism to manage water across all sectors towards achieving the national government's development objectives [NPC, 2012].

The Eutrophication Management Strategy for South Africa and the NWRS – NW&S MP duo have a bi-directional relationship. On the one hand, the Eutrophication Management Strategy for South Africa supports the NWRS - NW&S MP with greater resolution on eutrophication management, whereas, on the other hand, the NWRS - NW&S MP informs eutrophication management on the big-picture integrated water resource management priorities and perspective.

4.3.2 National Development Plan (2030) and National Water Security Framework

The National Development Plan (NDP), finalised in 2012, articulates the vision of development for the country and identifies key milestones and targets to be achieved in the various sectors. It sets out a detailed blueprint for how the country can eliminate poverty and reduce inequality by the year 2030. It was endorsed by Cabinet as a strategic framework to form the basis of future government detailed planning. The NDP envisions a South Africa where everyone feels free yet bonded to others; where everyone embraces their full potential, a country where opportunity is determined not by birth, but by ability, education and hard work [DWS, 2018b].

The NDP recognises the role of water in contributing to poverty eradication and social development. The most relevant programmes and targets articulated by the NDP in this regard include to-

- ensuring that people have access to clean potable water and that there is sufficient water for agriculture and industry, recognizing trade-offs in the use of water;
- reducing water demand in urban areas to 15% below the business-as-usual scenario by 2030;
- implementing a comprehensive management strategy, including an investment programme for water resource development, and bulk supply and wastewater management for major centres by 2012 with review every five years;
- developing regional markets for food, energy and water and putting in place water management agreements with neighbouring countries; and
- developing regional utilities to deliver some local government services on an agency basis where local or district municipalities lack capacity.

Additionally, the National Water Security Framework (NWSF) for South Africa reflects the high-level principles, scope and recommendations, distilled from the NDP and the work of the National Planning Commission (NPC), tasked with reviewing and ensuring its implementation. The NWSF endorses the UN Water definition of water security [UN Water, 2013], *viz. "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability"*. The NWSF supports the view of Jepson, *et al.* (2017) that *"… water security is less about obtaining water, and more about fostering human capabilities as they relate to water... It is not simply a state of adequate water – however defined – to be achieved, but rather a relationship that describes how individuals, households, and communities navigate and transform hydro-social relations to access the water that they need and in ways that support the sustained development of human capabilities and wellbeing in their full breadth and scope"*. This resonates with the ultimate vision, espoused by the NDP, of rising living standards, decreasing poverty and inequality, as well as restoring the dignity of the people of South Africa. The NWSF seeks to ensure the water security of the nation, and considers all the water uses that are currently important, as depicted in **FIGURE 27**. The NWSF endeavours to focus on national priorities, underpinned by a thriving economy [Nepfumbada & Seetal, 2020].

Increasing incidents of over-enrichment of water resources constitute a threat to all seven socio-economic water uses depicted in **FIGURE 27**, and hence also to a thriving South Africa economy, requiring the Eutrophication Management Strategy for South Africa to echo the sentiments of the NWSF: *"there now has to be a deliberate and concerted effort to ensure water security for South Africa's current and future socio-economic development needs"*.

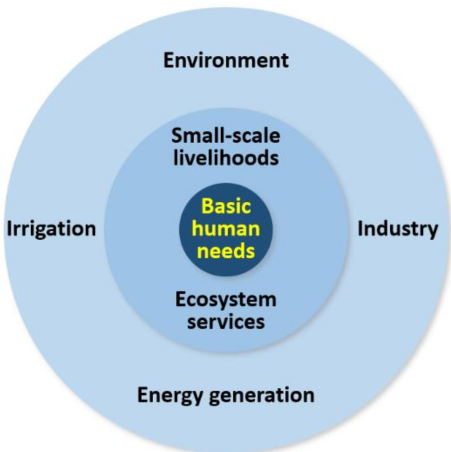

FIGURE 27: Important socio-economic water uses requiring water security [Nepfumbada & Seetal, 2020].

4.4 The Integrated Water Quality Management Policy and Strategy for South Africa (2017)

As of 2017, the Integrated Water Quality Management (IWQM) Policy and Strategy constitutes the apex policy and strategy for water quality management in South Africa (**FIGURE 28**).

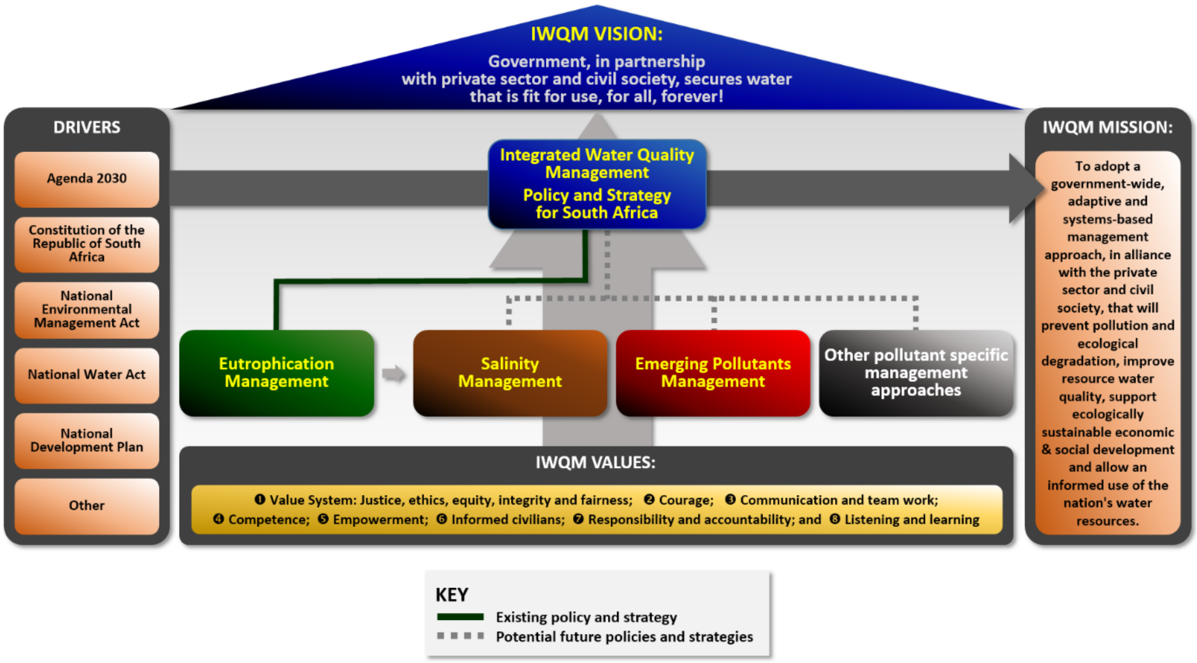

FIGURE 28: Relationship between the Integrated Water Quality Management (IWQM) Policy and Strategy for South Africa and the *Eutrophication Management Strategy for South Africa*.

The IWQM Policy aims [DWS, 2017c, p. 4]-

- to provide a coherent, consolidated, current and inclusive approach to water quality management;
- to align water quality management policy with current legislation and overarching policy, and provide resolution on matters not adequately addressed in current policy;
- to guide the further development of legislative and regulatory instruments;
- to inform the water resource management function;
- to address key operational aspects, such as adopting an integrated approach, broadening finance mechanisms, and improving knowledge and information in the execution of water quality management;
- to provide guidance on sustainable water use, especially, in as far as it relates to water quality management; and finally
- to provide the required framework for the development of related policies and strategies, *e.g.,* for the development of the Eutrophication Management Strategy for South Africa, as a sub-strategy.

Additionally, the IWQM Strategy considers and outlines the short, medium and long-term actions and interventions that need to be implemented to move the country forward towards achieving the IWQM Policy, and to ensure that the trajectory of declining water resource quality is arrested and turned around [DWS, 2017e, p. 3]. The IWQM Strategy identified eutrophication as a priority water quality issue, requiring intervention as a matter of urgency [DWS, 2017d, p. 9]. Various Strategic Objectives,[21] in the IWQM

[21] The Strategic Objective (SO) unique identifier numbers, used in the Integrated Water Quality Management Strategy for South Africa (2017), are given in brackets for ease of reference.

Strategy [DWS, 2017d], relate to eutrophication management and the roll-out of an Eutrophication Management Strategy for South Africa; these being that:

- Policies and Strategies impacting upon IWQM are harmonized (SO1a);
- IWQM is effectively supported by the NWA (36:1998) and/or the WSA (108:1997) (SO2a);
- IWQM is effectively supported by other legislation (SO2b);
- Partnerships/ stewardships are established and maintained (SO4a);
- Targeted/ strengthened compliance monitoring and enforcement of key polluting sectors is implemented (SO6b); and
- Sustained capacity for Government/ CMA/ sector to effectively manage and support IWQM through improved education and training is realised (SO11b).

The IWQM Strategy also calls for the development of policy and strategy to address diffuse sources of pollution and care should be taken to align the *Eutrophication Management Strategy for South Africa* with this vision.

The IWQM Policy and Strategy, 2017 will soon be supported by policy and strategy aimed at the resolution of eutrophication management. The collective role and guidance to be provided by this policy and strategy framework includes the promotion of innovation, presenting a broad outline of best approaches and ensuring consistent application nationally. It, however, should be acknowledged that the implementation of broad policy and strategy must be supported by water resource systems and catchment level planning. This is a critical aspect that is necessary to– integrate and address unique local characteristics and needs; pro-actively influence management interventions through informed options analysis and forward planning; and ultimately facilitate ecologically sustainable development.

CHAPTER 5: EVOLUTION OF EUTROPHICATION MANAGEMENT IN SOUTH AFRICA

The consideration of historic advancement together with an analysis of the present, and the extrapolation of past and present knowledge to the future, often assists with the development of a better understanding of trends, and with forward thinking. The following discussions reflect on eutrophication management related thinking that has emerged over time and recollect where we stand today. An understanding of the evolution of eutrophication management and its weaknesses will be used to propose improved ways of tackling problem areas and to develop progressive policy (Part 2) and appropriate roll-out approaches (Part 3) that should address current worsening nutrient over-enrichment trends; and limit and prevent excessive anthropogenic eutrophication in future.

5.1 Past paradigm

BOX 2: *"The past paradigm – summarised in a few words."*

The past paradigm is typified by gaining awareness of the effects caused by nutrient-laden wastewater and waste. In the past paradigm pollution control slowly emerged and initially took many forms – at first struggling to find traction as the universal approach to combat pollution and being restricted to areas of unacceptable impact; and later gaining momentum as the generally accepted approach to deal with pollution caused by nutrient-laden wastewater and waste. The past paradigm concludes with the realisation that the pollution control approach had to be substituted with a water quality management approach and that water resource requirements need to link with end-of-pipe effluent control.

5.1.1 The period prior to the industrial age

In the early years, the measures closely resembling eutrophication management world-wide, if at all, were limited to general waste and wastewater handling practices. Even though municipal water supply and sanitation goes back as far as 600 BC to ancient Rome [Havlíček & Morcinek, 2016], the use of inventions, such as the water closet in Elizabethan times (second half of the 16th Century), was adopted by only a very few households [Wall, 2018].

The first recorded proclamation in South Africa that dealt with water pollution and wastewater handling goes back to 10 April 1655. On this day the Dutch Administration in the Cape of Good Hope issued a *"placaat"* (a public notice) that prohibited pollution of selected streams draining the slopes of Table Mountain [Thompson, 2016]. According to the public notice, fines would be imposed on people washing in, or dumping refuse into, the streams that supplied freshwater through *"grachts"* (canals) to the downstream settlements [Wall, 2018]. However, during those days water quality received limited attention, with the bulk of the focus on consumptive water use and related matters.

5.1.2 The 19th Century

From the late 18th Century onwards, the pace of change started to increase rapidly in response to far-reaching social and institutional changes, together with medical, scientific and technological advances. With the first recorded discovery of diamonds in 1867 near Hopetown [Shigley, 2017], and of gold in 1886 on the Witwatersrand [Richardson & Van Helten, 1984, p. 319], South Africa was converted from a predominantly agricultural society to the largest producer of gold and one of the largest producers of diamonds in the world. However, in much of 19th Century South Africa, particularly in the rural areas, significant change was slow. The all-inclusive population of just over 5 million people at the turn of the

19th Century [Hancock, 1962] was sufficiently dispersed so that the disposal of all forms of waste could take place with very little chance of harming anyone else. Thus, there was little, to no need, for any kind of regulation regarding anthropogenic eutrophication causes [Wall, 2018].

5.1.3 The 20th Century up to 1956

With the advent of the 20th Century, urban centres and mining towns, such as Johannesburg and its sister gold mining towns, started to expand more rapidly. With the establishment of the first engineered schemes, early in the 20th Century, to bring water from more distant places to where it was needed in urban centres [Wall, 2018], increasing return-flows were generated. The first statute containing water quality management related provisions was the Public Health Act of the Union of South Africa, 1919 (Act No. 36 of 1919), [22] which prohibited local authorities from discharging effluents into natural watercourses[153], irrespective of the quality. This legislation also permitted the Minister of Health to lay down standards for purified effluent, but these powers were never exercised [Wall, 2018]. Additionally, in 1951, the South African Bureau for Standards (SABS) published standards for the discharge of effluent to streams, although these were more in the form of guidelines with no obligation to enforce them [Osborn, 1988].

The first municipal WwTWs commissioned in South Africa – by today's standards, extremely small and using primitive technology – commenced operations in Bloemfontein (November 1904) and in Wynberg (January 1905), followed by Pietermaritzburg (1908) [Osborn, 1988]. In these cases, the improved resultant effluent was irrigated over adjacent land. In all other urban centres, wastewater, if it was collected at all, was irrigated on land in an untreated state [Wall, 2018].

5.1.4 The period following 1956 up to 1994

By 1956 it was becoming apparent that reconciling water supply with water demand would be increasingly difficult and that the reuse[129] of growing volumes of wastewater would have to play a major role in the management of the country's scarce water resources. The Water Act, 1956 (Act No. 54 of 1956)[23] brought radical changes to how wastewater was viewed and basically reversed the prohibition on the discharge of effluent into natural watercourses, as was previously enforced through the Union Health Act (36:1919) [DWAF, 1991]. The 1956 Act, consequently, made it mandatory that effluent must be treated to acceptable standards and returned to the watercourse from which the water was originally obtained.

As time passed, riverine ecosystems have been systematically modified on increasingly large scales. At the turn of the 20th Century, a growing population of just over 44 million people [Stats SA, 2003] has increased the needs for food supply and wastewater handling. The associated progressive industrialisation and infrastructure programmes necessitated the building of large dams for water security purposes. These factors increasingly contributed to the increasing prevalence of anthropogenic eutrophication of surface water resources in the period following 1956.

The linkage between aquatic plant growth, nutrients and human activities (eutrophication) was recognized as a threat to South African surface waters almost seven decades ago and the first impacts thereof became apparent in the 1950s and reaching problematic levels in the 1960s [Walmsley & Butty, 1980; Zohary, et al., 1988; Van Ginkel, 2011; Cholnoky, 1958; Allanson & Gieskes, 1961]. In 1962, the then Department of Water Affairs[24] (DWA) published the Regional Standards for Industrial Effluent; specifying a series of uniform Waste Discharge Standards (WDSs). This was the first rendition of what are today known as the

[22] Hereafter, referred to as the Union Health Act (36:1919).
[23] Hereafter, referred to as the WA (54:1956).
[24] Currently the Department of Water and Sanitation (DWS).

General and Special Standards for the purification of Wastewater or Effluent. Importantly, the Notice included a Special Standard for phosphorus of 2 mg/ℓ orthophosphate [GN R.553, 1962].

Eutrophication monitoring in South Africa commenced in the early 1970's – at the time, mostly being done as *ad hoc* monitoring surveys and research projects supported by the WRC up to about 1985 [Toerien, et al., 1975]. Also worth mentioning, is that the South African born James L. Barnard, during this time, pioneered Biological Nutrient Removal (BNR) to, *inter alia*, solve the city of Johannesburg's phosphorus and nitrogen challenges. Today, he is recognized internationally for developing the BARNDENPHO and Phoredox Processes, which constitute the basis for all biological and nutrient removal process configurations in use [Nicholls, et al., 1986].

In 1980, a revised Special Standard, based on best available wastewater technology [Taylor, et al., 1984], for phosphorus of 1mg/ℓ orthophosphate was published [GN R.1567, 1980] and in 1984 this Special Standard for phosphorus of 1mg/ℓ orthophosphate was included in the *General and Special Standards for the purification of Wastewater or Effluent* (**TABLE 11**) [GN R.991, 1984].

TABLE 11: General and Special Standards for the purification of Wastewater or Effluent: Selected constituents, relevant to excessive primary production.

CONSTITUENT	GENERAL STANDARD for less sensitive catchments	SPECIAL STANDARD for more sensitive catchments
Chemical Oxygen Demand *(after applying the chloride correction)*	≤75 mg/ℓ	≤30 mg/ℓ
Suspended solids	≤25 mg/ℓ	≤10 mg/ℓ
Nitrogen as free and saline ammonia (NH_3)	≤10 mg/ℓ	≤1 mg/ℓ
Nitrogen as nitrates (NO_3^-)	-	≤1.5 mg/ℓ
Phosphorus as orthophosphate (PO_4^{3-})	-	≤1 mg/ℓ

These Special Standards for phosphorus were made applicable in specific catchment areas by means of specifying them in schedules in the relevant regulations, *viz.* 73 catchment areas, as listed in GN R.533 (1962); and 7 catchment areas, as listed in both GN R.1567 (1980) and GN R.991 (1984).

Pretorius (1983) and Toerien (1984) both criticised the decision to include a blanket (uniform) phosphorus standard of 1 mg/ℓ orthophosphate for all sensitive catchments, on the grounds that the differences in phosphorus-receiving capacity of impoundments was ignored and that in some catchments the contributions from diffuse sources was so high that removal of point sources would have negligible effects on the trophic status of impoundments [Grobler & Silberbauer, 1985].

Later legislative amendments, notably the Water Amendment Act, 1984 (Act No. 96 of 1984), broadened water quality management. Industrial effluent, and sources other than effluent, *e.g.,* water which arises as a by-product from industrial and mining activities and seepage or stormwater runoff from a site, were made subject to pollution control regulations. The State was also given powers to prevent pollution before it takes place [DWAF, 1991].

The disposal of land-derived wastewater to the marine environment of South Africa was governed under Section 21(1) of the WA (54:1956), which required that such wastewater must be treated in accordance with the requirements as prescribed by the Minister, in this case the *General and Special Standards for the purification of Wastewater or Effluent* [GN R.991, 1984], and that the treated wastewater must be returned to the sources of abstraction. Since these standards had not been developed with sea outfalls in mind, wastewater discharges to estuaries, surf zones and the offshore marine environment were mostly exempted from meeting the prescribed standards, as well as from being returned to the sources of abstraction [DWAF, 2004].

In 1985, the DWA initiated the first eutrophication-focused monitoring programme, *i.e.,* the Trophic Status Project (TSP), which covered the 7 sensitive catchments, as listed in GN R.1567 (1980) and GN R.991 (1984), respectively. The TSP would lay a solid foundation for the National Eutrophication Monitoring Programme

(NEMP), to be designed and implemented years later, in that it highlighted the extent of the problem at a national scale in sensitive catchments, and also provided a database to be used during the design of the NEMP [DWAF, 2002].

In 1991, the then Department of Water Affairs and Forestry[25] (DWAF), adopted its new water quality management policy, entitled *Water Quality Management Polices and Strategies in the Republic of South Africa*, concluding an era of pollution control and entering an era typified by the Receiving Water Quality Objectives Approach[119] [DWAF, 1991]. With the adoption of this approach, water quality management would hence forth focus on cumulative impacts on water resources, rather than on individual point sources of pollution [DWS, 2017b]. Full implementation of this approach in the absence of supporting legislation, *i.e.,* until the promulgation of the NWA (36:1998) in 1998, however, would prove to be difficult.

5.2 Current paradigm

BOX 3: *"The current paradigm – summarised in a few words."*

The current paradigm starts off with the new democratic dispensation for South Africa that saw the advent of a new constitution, establishing the human rights to an environment that is not harmful and to sufficient water supply. In the current paradigm, the foundation for integrated water quality management had been laid with the promulgation of new environmental and water legislation. Water quality management would be characterised by a concept to integrate water quality management efforts in the context of ecologically sustainable development and attempts to operationalise the Receiving Water Quality Objectives Approach.

5.2.1 The years leading up to present-day eutrophication management, 1994 to 1998

1994 heralded a turning point in the history of South Africa. The *"interim"* Constitution of the Republic of South Africa, 1993 (Act No. 200 of 1993), at the time, and the *"new"* Constitution (108:1996) – in particular Sections 24 on *"an environment that is not harmful …"* and 27 on *"access to sufficient water"* – prompted a revision of national water policy and legislation. The White Papers on *Water Supply and Sanitation Policy* (1994) and a *National Water Policy for South Africa* (1997) paved the way for the promulgation of the WSA (108:1997) and the NWA (36:1998) on 27 November 1997 and 20 August 1998, respectively, the latter act replacing the WA (54:1956). Collectively these statutes[26] predominantly focus on the freshwater[62] value chain – *"from resource to source to resource".*[27]

All water hence forth, would be regarded as being part of a common good, kept in public trust on behalf of all persons by the Minister of Water and Sanitation [DWAF, 1997; NWA, 1998, S.3]. As such, the DWS is mandated, *inter alia*, to protect water resources and water users; to meet the basic human needs of present and future generations; to promote equitable access to water; and to manage the water quality of all water resources, while supporting ecologically sustainable development.

The NWA (36:1998), furthermore, recognises that water quality is inextricably linked with water quantity (typically water flow), in stream and riparian habitats and to aquatic biota integrity, all of which are collectively referred to in the Act as the *"resource quality"*. For water resources to be able to continuously sustain economic growth and social development, the quality (or *"resource quality"*)

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25 Currently the Department of Water and Sanitation (DWS).

26 **Annexure E** provides a synopsis of important provisions in these two acts and their roles in eutrophication management.
Annexure F is included in support of **Annexure E** and focuses on provisions for the making of regulations and the prescribing of compulsory national standards which can be employed to enhance the efficacy of eutrophication management.

27 Until the promulgation of the National Environmental Management: Integrated Coastal Management Act, 2008 (Act No. 24 of 2008), more than forty South African sea outfalls had been formalised through authorisations issued in terms of the (previous) WA (54:1956) and the (current) NWA (36:1998) [Oelofse, et al., 2004].

of such water resources needs to be maintained within certain pre-determined parameters. These water resource parameters, or statutory Resource Directed Measures (RDMs), are represented by the water resource Management Class, Resource Quality Objectives (RQOs) and the Reserve[122]. The NWA (36:1998), additionally, makes provision for Source Directed Controls (SDCs) to control sources of negative impacts on resource quality, aiming to comply with the determined RDMs. SDCs include measures such as water use registration, authorisation, directives, prosecution and economic incentives such as levies and fees. This approach recognises both the needs for upstream water use and development, and downstream protection of aquatic ecosystems and user water quality requirements.

The National Eutrophication Monitoring Programme (NEMP) (**Annexure G**) gained momentum and was implemented in 2002. In 2003, the Strategic Framework for Water Services was published to serve as an umbrella framework for the water services sector. This Framework set overall goals and outlined institutional and operational frameworks necessary for achieving the Framework's goals. In 2006, the Resource Directed Management of Water Quality Policy and Strategy series was published to give substance to resource water quality management. With the publication of the IWQM Policy and Strategy in 2017, a new integrated approach to water quality management across key government departments and the sector was introduced. The IWQM Policy and Strategy serves as an umbrella policy and strategy for water quality management and, thus, also for eutrophication management policy and strategy, in South Africa.

The evolution of the water quality management supporting legislation and policy over time, and some implications for eutrophication management, are summarised in **FIGURE 29**.

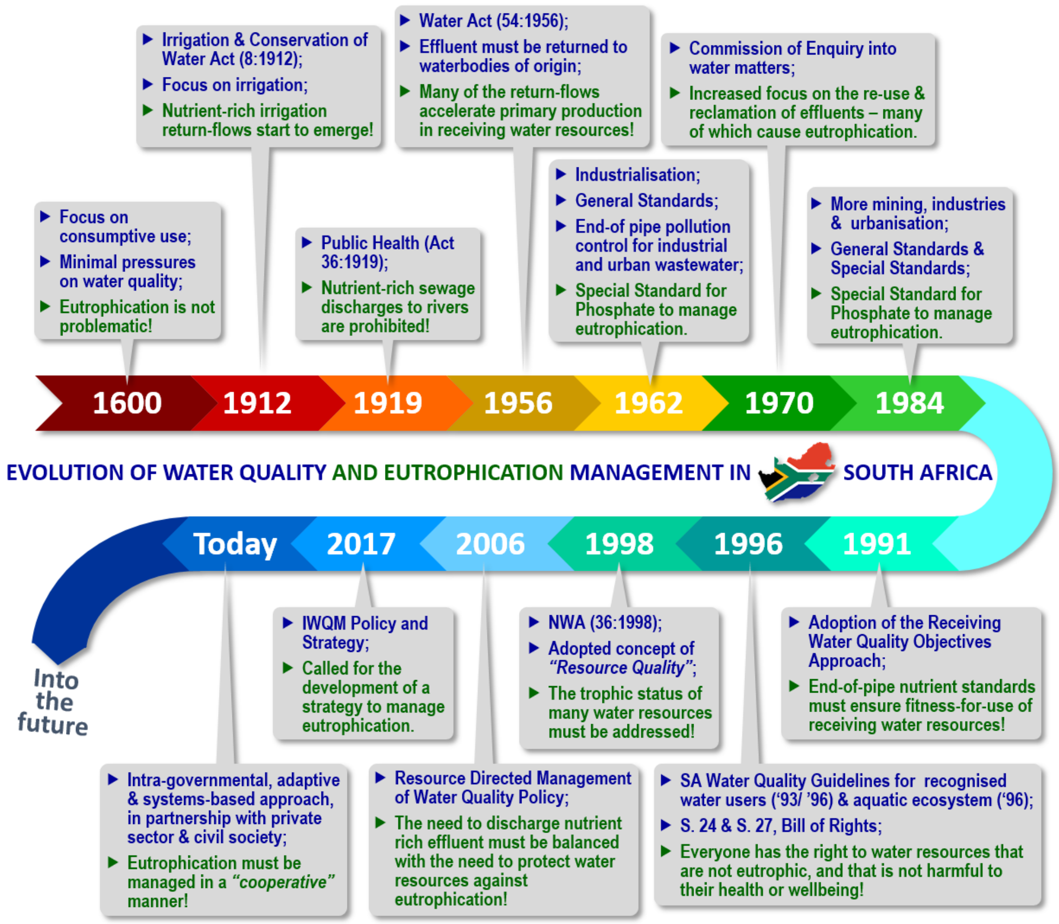

FIGURE 29: The evolution of eutrophication management in South Africa.

5.2.2 Contemporary eutrophication management

Although excessive nutrient-loading of water resources is caused by both point and diffuse sources of water pollution, eutrophication management measures, currently, focus mostly on the regulation of point sources of nutrient-loading. The freshwater[62] value chain (**FIGURE 30**), consisting of– upstream supply operations; consumptive water uses; and downstream discharge of wastewater return-flows, some with a high nutrient content, provides a handy basis from which present day point source-focused eutrophication management can be conceptualised. The ensuing discussion evaluates whether the statement, *"No value chain is stronger than its weakest link"*, also holds true for the water value chain, especially in the context of escalating anthropogenic eutrophication observed in multiple receiving water resources.

The freshwater value chain has a two-leg configuration, *i.e.* (1) a municipal supply and return-flow leg; and (2) a raw water supply and return-flow leg. Regulatory responsibilities are shared across these two legs, with WSAs (municipalities) generally holding regulatory responsibility over leg (1) and the DWS over leg (2), often presenting cooperative governance challenges. WSAs are required to register the qualifications of operators of WwTWs. Until recently, DWS, from an effluent point of view, had only been interested in the final end-of-pipe discharge quality of the wastewater return-flows from both legs. DWS, thus, has little insight in the volumes and qualities of feed-water being received by WSAs at municipal WwTWs from their client sectors.

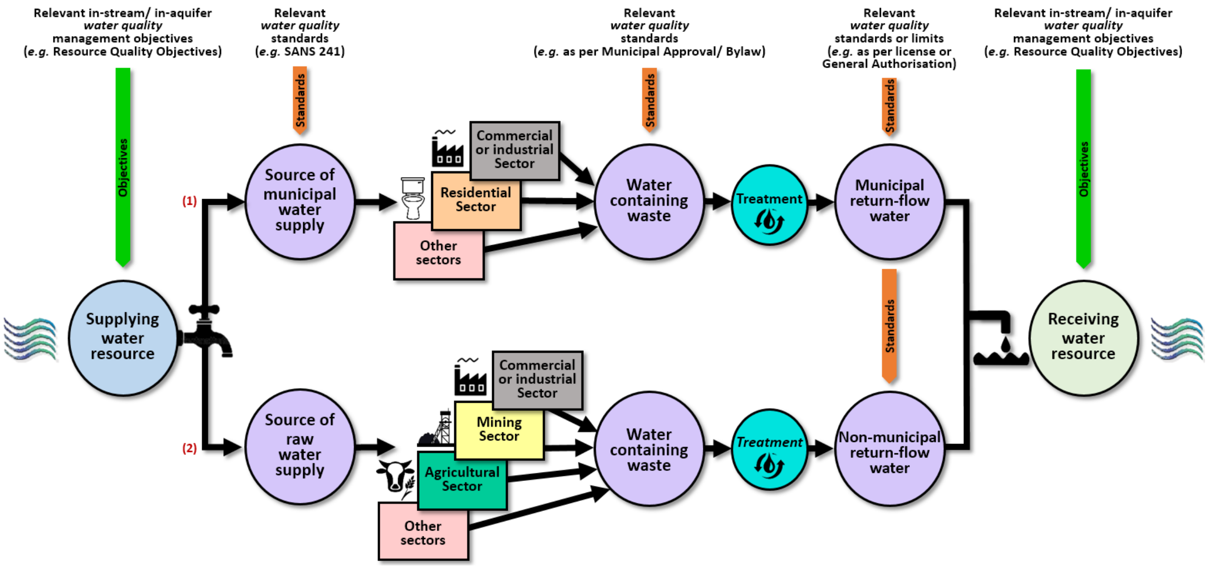

FIGURE 30: The freshwater value chain: *"From resource to source to resource"*.

In contemporary eutrophication management, there are many provisions in the NWA (36:1998), today, which are at the disposal of the regulator to facilitate improved eutrophication management and water resource protection, but which are, for some reason, not being fully employed. Some of these provisions are important, and include:

- The WDCS, which could facilitate the limitation and prevention of nutrient-loading by the application of the polluter-pays[113] principle [NWA, 1998, S.56];
- The establishment of Catchment Management Strategies (CMSs), containing eutrophication specific interventions – tailor-made for each Water Management Area (WMA) and sub-catchments to address specific eutrophication management needs [NWA, 1998, S.8];
- Regulations to regulate the design, construction, installation, operation and maintenance of WwTWs, owned by both the private and public sectors [NWA, 1998, S.26(1)(e)]. These regulations will specifically

help to improve the current situation with respect to municipal WwTWs by addressing poor maintenance, timeous upgrading, and utilisation of works over their design-capacity;

- Regulations to regulate or prohibit any activity in order to protect a water resource, instream or riparian habitat, from the effects of excessive nutrient-loading [NWA, 1998, S.26(1)(g)];
- Regulations prescribing waste standards, which specify the quantity, quality (concentrations of nutrients) and temperature of waste, which may be discharged or deposited into, or allowed to enter, a water resource [NWA, 1998, S.26(1)(h)]; and
- Regulations requiring that waste discharged or deposited into or allowed to enter a water resource be monitored and analysed, and prescribing methods for such monitoring and analysis [NWA, 1998, S.26(1)(j)]. Such data and information should be uploaded onto the DWS's Integrated Regulatory information System (IRiS), or suitable alternative system, to enable the efficient interrogation of data.

Although the NWA (36:1998) has introduced various statutory Resource Directed Measures (RDMs) [NWA, 1998, S.15] to, *inter alia*, ensure fitness-for-use of receiving water resources, the operationalising of the Receiving Water Quality Objectives Approach has proven to be elusive. It is critical that receiving water quality requirements for nutrient reduction must be integrated with water use authorisations to address the effects of anthropogenic eutrophication.

In many cases, room for better integration also exists within a few WSA (108:1997) provisions. For instance, the integration with Municipal Approvals of water use [WSA, 1997, S.7(2)], water services development planning and the establishment of Water Services Development Plans (WSDPs) [WSA, 1997, S.16] and information management [WSA, 1997, S.67].

The National Environmental Management: Integrated Coastal Management Act, 2008 (Act No. 24 of 2008)[28] would ultimately assume full regulatory responsibility for marine water quality management. The regulation of anthropogenic causes of marine eutrophication that emanate from coastal areas may potentially present further integration challenges. The regulation of inland anthropogenic activities, which, through river runoff, potentially impact excessively on the trophic status of estuarine and coastal marine waters, however, remains under the NWA (36:1998). The addition of the NEM ICMA (24:2008) would, thus, fully extend the management of eutrophication to address the entire water value chain – *"from resource to source to resource to sea"*, albeit that the regulation of inland and coastal marine waters would be administered by different government departments [DEA, 2014].

5.3 Future paradigm

BOX 4: *"The future paradigm – summarised in a few words."*

The future paradigm, in the short term, will probably be typified by a consolidation of water quality management efforts, striving to fully utilise and to refine all available legal and policy instruments. In the longer term, the future paradigm will have to yield innovative solutions and approaches to appropriately address anthropogenic eutrophication and to realise and guarantee ecologically sustainable development for generations to come.

5.3.1 Matters to receive attention in the short term

Van Niekerk (2000) observed that there has been widespread non-compliance of WwTWs to the phosphorus standard of 1 mg/ℓ orthophosphate, whereas Harding (2017) noted that a phosphorus standard of 1 mg/ℓ orthophosphate may, in some circumstances, be too lenient. These two related observations raise several important points that should be addressed soon, *viz.*:

- Room for better management integration exists;

[28] Hereafter, referred to as the NEM ICMA (24:2008).

- Feasible and appropriate Waste Discharge Standards (WDSs) should be developed and implemented;
- The Receiving Water Quality Objectives Approach must be operationalised. Harding (2008) proposed an approach that includes the calculation of Total Maximum Daily Loads (TMDLs)[143] for dams;[29]
- The role and feasibility of technology to treat nutrient-laden wastewater should inform processes to improve eutrophication management. The Best Practicable Environmental Option (BPEO)[14] should be implemented;
- All water uses must be lawful and, where necessary, valid water use authorisations must be in place;
- Compliance monitoring and enforcement must be intensified to deal with unlawful and non-complying water uses; and
- Water users must take due responsibility to appropriately limit their contributions to excessive eutrophication (duty of care[42]) and in cases where they do not, the regulator should step in.

Additionally, future actions would, in the short term, include addressing priorities, such as:

- Full implementation of all the instruments in the NWA (36:1998) that are available, and which would aid eutrophication management;
- Protection of high yield and strategic water source areas, and related ecological infrastructure that offer water quality improvement functions;
- The implementation of buffer areas to protect water resources against diffuse sources of nutrient-laden pollution;
- Ensuring that national and regional eutrophication monitoring programmes resume full operation.
- If feasible, these national and regional eutrophication monitoring programmes should be augmented and expanded with volumetric, nutrient and chlorophyll-α related data that can be obtained from the monitoring of raw feed water that is abstracted, for instance, by Water Services Institutions for the purpose of water purification and supply. Such abstraction-related data should be available electronically through an appropriate information management system and not held in hard copy only;
- Resource water quality data and information must be paired with water resource flow data and information to allow for the consideration of nutrient-loading;
- The integration of Earth observation into eutrophication monitoring, making use of satellite Earth observation (remote sensing) for the monitoring of cyanobacterial blooms and eutrophication in South Africa's medium- and large-sized freshwater bodies, can be integrated with the National Eutrophication Monitoring Programme (NEMP). The chlorophyll-α (Chl-α) estimates from satellite imagery should be incorporated into the Water Management System (WMS) of the DWS. This will supplement data gaps and ensure greater data and information coverage in the NEMP [Matthews & Bernard, 2015];
- The availability of, and the access to resource quality data, by public citizens, should be improved, to increase eutrophication awareness. Where feasible, the use of new technology solutions, such as the CyanoLakes cellular telephone application that was developed in partnership with the WRC, can be considered and promoted;
- Compliance monitoring should be extended to also include volumetric effluent data and information, in addition to water quality data and information, to allow for the consideration of nutrient-loading from WwTWs;
- It must be made compulsory and simple for water users to upload both volumetric and water quality data and information on IRiS (or approved alternative data and information management system), instead of only submitting hard copy records to the regulator, as may be required by the applicable water use authorisations;
- Water quality and volumetric data and information, originating earlier within the water value chain, have the potential to put additional water quality intelligence in the hands of the DWS that could assist

[29] Also see **CASE STUDY 1**:The *"Plan"* stage – The purpose of Total Maximum Daily Loads (TMDLs).

with nation-wide improving of the performance of municipal WwTWs. These data and information must be uploaded for interrogation on a national information management system;

- Better cooperation with government, private sector and civil society role-players needs to be put into action and must be maintained; and
- Providing technical support to local government, where necessary, and ensuring that municipalities have appropriate bylaws in place to manage the causes of eutrophication early in the water value chain and to provide for the monitoring of water quality and volume.

5.3.2 Potential innovation in the longer term

In the longer term, the focus can shift to attaining more innovative and progressive solutions to address eutrophication problems.[30] These may include the following:

- Developing and implementing Total Maximum Daily Loads (TMDLs) to link waste discharges to receiving water assimilation capacity;
- The regulation of diffuse water pollution mostly as it relates to land care and land-use management. Innovative arrangements and approaches, to address this source of nutrient-loading, are necessary;
- Escalating water demands being supplied, which often translate into the increasing generation of wastewater return-flow volumes, which require treatment prior to being discharged. More emphasis is required on mechanisms to promote reuse and recycling strategies, as a measure to reduce demand, and hence to reduce the contributions of wastewater return-flows to nutrient-loading of receiving water resources;
- Bio-manipulation, fish-harvesting and food-web manipulation to address the symptoms of eutrophication can be considered;
- The rehabilitation and restoration of affected water resources, including the implementation of bio-remediation initiatives, such as the Harties Metsi-a Me/ Hartbeespoort Dam Biological Remediation Project [Mitchell, et al., 2016], in affected water resources should be considered and supported where merited;
- The use of technology solutions, such as the use of Solar-Powered Reservoir Circulators (Solar-Bees). These instruments are floating solar-powered reservoir long distance circulation pump systems, used to mix water in-lake. It can greatly accelerate the biological and solar processes that clean-up water and can be considered as a feasible reactive in-lake intervention. Care, however, must be taken in acquiring and applying these instruments effectively and correctly to produce the necessary circulation within the epilimnions of water resources, as pumping nutrient-rich water from the hypolimnion during summer periods or increasing the turbidity through increased turbulence in the water column, may be counter-productive in preventing eutrophication impacts; and
- The introduction of zero-phosphate detergents in South Africa [Quayle, et al., 2010] should be pursued, linked to consumer education. Low- or no-phosphorus detergents do not foam as well as detergents with phosphates and may encourage (especially rural) users to use even more dangerous chemicals to create the same level of foaming (seen as analogous to cleaning) that was achieved by phosphate detergents [Pers. coms. Thornton, 2021].

[30] Interventions need sufficient funding and support for scientific monitoring of the outcomes over a long period – several years or even decades.

CHAPTER 6: CONCLUSION

Part 1 presented the South African eutrophication context by setting the scene with a summation of the key challenges being experienced in South Africa, followed by a more general, but comprehensive, problem declaration in tabular form that was structured in accordance with the **D**river-**P**ressure-**S**tate-**I**mpact-**R**esponse (DPSIR) framework method.

Background scientific information has been provided on the subject of *"Eutrophication"*, which *inter alia* provides definitions; explains the significance of nutrients and human effects on nutrient cycling; motivates the selection of phosphorus and nitrogen as limiting nutrients; examines the role and application of trophic status indices to classify water resources according to the amount of biological productivity they sustain; and discusses the role of the catchment and catchment eutrophication management. Importantly – it is pointed out that two types of eutrophication exist, namely natural and anthropogenic eutrophication; and that the Eutrophication Management Strategy for South Africa is to focus on anthropogenic eutrophication and excessive nutrient-loading.

The purpose, scope and structure of the Eutrophication Management Strategy for South Africa document were described, also explaining the development and the stakeholder participation processes that were followed to enrich and develop the Strategy.

The wider policy, strategy and legal contexts were explored by looking at the implications for the management of eutrophication in the international sustainable development agenda, key pieces of national legislation and selected executive strategies, plans or frameworks identified. As such, eutrophication-linkages with Agenda 2030, and the nature and character of *"sustainable development"* were succinctly discussed. Guidance was sourced from the Constitution, NEMA (107:1998), the NWA (36:1998) and from the WSA (108:1997), and the NWRS2, the NW&S MP, the NDP and the NWSF. The implications of these documents were unpacked and summarised. Finally, the direction-giving implications of the IWQM Policy and Strategy were considered and deliberated.

Part 1 concluded with a focused analysis of the past, present and future eutrophication management paradigms. Reflecting on the evolution of eutrophication thinking and management is useful when extrapolating trends and attempting to project possible future change. Matters to receive attention in the short term and potential innovation in the longer term were matters that, amongst others, were identified and deliberated.

Part 1 shows that well-articulated goals, supported by clear and focused ground rules are necessary to direct eutrophication management. These goals should now be developed as a *"vision"*, a *"mission"*, a *"goal"* and *"objectives"* and the ground rules as *"policy statements"* to guide addressing all eutrophication-related challenges within the South African context.

EUTROPHICATION MANAGEMENT POLICY FOR SOUTH AFRICA

Part 2

PART 2: EUTROPHICATION MANAGEMENT POLICY FOR SOUTH AFRICA

PHOTO 2: ***"WATER POLLUTION AFFECTS EVERYONE!"*** © J.J. VAN WYK

CHAPTER 1: INTRODUCTION

In general terms, *"policy"* defines ground rules, delineates intent and an expression of political mandate, and specifies desired outcomes [Presidency, 2020]. This part of the document identifies several succinct policy statements that are regarded as most pertinent to eutrophication[58] management in South Africa. Collectively these policy statements provide an extension of the over-arching Integrated Water Quality Management (IWQM) Policy – for the resolution of eutrophication management, nationally.[31] As such, some eutrophication management policy statements are complementary to the IWQM Policy, *i.e.* rephrased or adjusted to reflect and add a eutrophication focus, whereas others are supplementary and new.[32] Although the policy on eutrophication management has a standing in its own right, it is supported with a strategy on eutrophication management (Part 3) that assists implementation. For convenience, relevant policy statements are referenced only within the eutrophication management strategy, instead of repeating them throughout.

The eutrophication management policy making process follows that of Sector Policies [Presidency, 2020], which are policies that departments and municipalities must strive to execute, and which are derived from their respective mandates. These policies find expression for implementation *inter alia* through Strategic Plans, municipal Integrated Development Plans (IDPs), Annual Performance Plans (APPs) and municipal Service Delivery Budget and Implementation Plans (SDBIPs) [Presidency, 2020]. The eutrophication management strategy is to assist in linking policy with catchment[21] and other strategies and plans for expression. With the rolling-out of the IWQM Policy and Strategy for South Africa, and the implementation of formalised eutrophication management, lessons are being learned, old views are being renewed, and new approaches are forged. All this is necessary to stay abreast of changing circumstances in a dynamic environment[51], and to *"stay ahead of the curve"*!

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[31] Care was taken to develop harmonising policy. In an unlikely event of contradicting policy views – the higher policy prevails.

[32] The National Policy Development Framework (NPDF), as adopted by Cabinet on 2 December 2020, makes provision for six broad categories of generic policy. Policy directives are amongst these and constitute formal instructions that must be executed by all affected policy implementers. A policy directive usually encapsulates instructions of a technical nature that do not require changes to higher level policies. Additionally, policy directives may reflect significant strategic or policy decisions. A policy directive communicates changes to the interpretation or application of policies and legislation. They can come in different forms, such as prescripts that interpret and clarify legislation regarding procedures, processes and practices that must be followed. The Eutrophication Management Policy follows the prescripts associated with policy directives [Presidency, 2020, p. 11].

CHAPTER 2: VISIONARY PERSPECTIVE

It is imperative that public policy have a clear vision and that it must set out its ultimate intention [Presidency, 2020]. Eutrophication management in South Africa subscribes to the IWQM Vision and Mission [DWS, 2017b], *viz.*:

Vision: ***"Government, in partnership with private sector and civil society, secures water that is fit-for-use, for all, for ever."***

Mission: ***"To adopt a government-wide, adaptive and systems-based management approach, in alliance with the private sector and civil society, which will improve resource water quality, prevent pollution and ecological degradation, support ecologically sustainable economic and social development and allow an informed use of the nation's water resources."***

As such, eutrophication management has an important and specific role to play in the advancement of the above stated vision and mission. This role is embodied in the following goal for eutrophication management in South Africa:

Goal: ***"To manage eutrophication effectively in order to protect aquatic ecosystems and to secure water resources that are fit-for-use."***

A collage of different objectives offers further context to the Goal, and to subsequent policy development. This collage of different objectives can be grouped into two *"layers"* of objectives and associated policy statements, pertaining to eutrophication management. For practicality purposes, distinction is made between a *"first layer"* consisting of Chief Objectives, and a *"supporting layer"* consisting of Complementing Objectives for eutrophication management. Collectively, these two distinct *"layers"* of objectives for eutrophication management must strive to contribute towards realising the IWQM Vision and Mission and the national Eutrophication Management Goal. These objectives are listed below:

The Chief Objectives for eutrophication management are to:

- **limit anthropogenic[6] nutrient-loading of water resources[158];**
- **reduce excessive primary production[115] in surface water resources;**
- **protect aquatic ecosystems[7] and their biological diversity;**
- **secure water resources that are fit-for-use on a continuous basis; and**
- **support ecologically sustainable development and justifiable socio-economic growth.**

Complementing Objectives for eutrophication management are to–

- **resource eutrophication management, *inter alia*, by securing funding, providing human capital and equipping responsible parties;**
- **promote research in relation to management of eutrophication and control of anthropogenic sources of nutrient enrichment[100];**
- **promote management cooperation within and between government, private sector and civil society;**
- **promote transparency through stakeholder consultation, eutrophication-related communication and awareness creation; and**
- **facilitate capacity building and empowerment of role-players.**

Policy statements supportive of the objectives, as listed above, and that are regarded as most pertinent to eutrophication management in South Africa, are listed in **TABLE 12**. The table also gives indications of whether the policy statements are regarded as *"existing"*, *i.e.,* complementary to the IWQM Policy and rephrased or adjusted to reflect and add a eutrophication focus; or as *"new"*, *i.e.,* supplementary to the IWQM Policy:

TABLE 12: List of pertinent policy statements for eutrophication management in South Africa.

STATEMENT #	POLICY STATEMENT	STATUS
	Policy statements in support of the Chief Objectives for eutrophication management	
POLICY STATEMENT 1	Application of management instruments for environmental compliance in eutrophication management	*New*
POLICY STATEMENT 2	The Mitigation Hierarchy for decision-making on eutrophication	*Existing*
POLICY STATEMENT 3	The Differentiated Approach for the control of excessive nutrient-loading	*Existing*
POLICY STATEMENT 4	The application of the Precautionary Principle	*Existing*
POLICY STATEMENT 5	The Receiving Water Quality Objectives Approach applied to eutrophication management	*Existing*
POLICY STATEMENT 6	A life cycle view on nutrient-loading	*New*
POLICY STATEMENT 7	Incentive-based regulation	*Existing*
POLICY STATEMENT 8	Nature-based solutions	*New*
POLICY STATEMENT 9	The application of the Best Practicable Environmental Option	*New*
POLICY STATEMENT 10	Holistic eutrophication management	*New*
POLICY STATEMENT 11	Eutrophication management responsibility and accountability	*New*
POLICY STATEMENT 12	Monitoring	*Existing*
POLICY STATEMENT 13	Information management	*Existing*
POLICY STATEMENT 14	Water resource assessment and planning to inform decision-making	*Existing*
	Policy statements in support of the Complementing Objectives for eutrophication management	
POLICY STATEMENT 15	Resourcing of eutrophication management	*New*
POLICY STATEMENT 16	Promotion of eutrophication-related research	*Existing*
POLICY STATEMENT 17	Transparency	*Existing*
POLICY STATEMENT 18	Technical capacity to take eutrophication management action	*Existing*
POLICY STATEMENT 19	Cooperative eutrophication management	*Existing*

FIGURE 31 provides a contextual outline of the Eutrophication Management Policy.

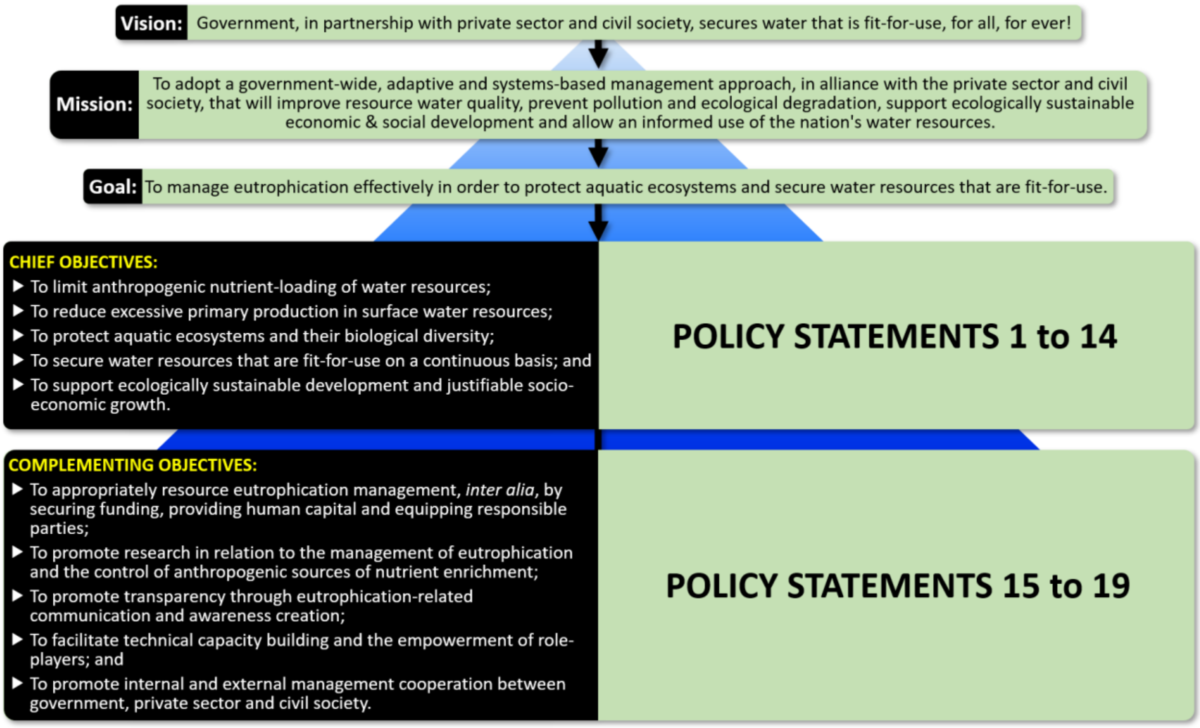


FIGURE 31: Outline of the Eutrophication Management Policy.

The individual policy statements are unpacked in more detail, next in Chapter 3 of Part 2, which provides the policy premise, definitions of policy intent and a concluding statement on the status of the particular policy statement.

CHAPTER 3: POLICY INTENT

Recognising that:

(1) Nutrient[97] over-enrichment of water resources from an anthropogenic origin represents a water resource pollution threat that impacts on the integrity of most South African aquatic ecosystems, and the fitness-for-use of receiving water resources; and

(2) Excessive nutrient-loading originating from both point[112] and diffuse[38] sources of pollution, causes an adverse impact on social development and economic growth; and

(3) Anthropogenic eutrophication is considered to be a problem that will contribute towards an increasing occurrence of water quality[156] challenges country-wide, and has the potential to become a crisis, unless appropriate national policies and strategy are implemented; and

(4) Eutrophication management has been neglected over the past decades and this has resulted in a loss of human resource capacity, institutional memory, management information and a general understanding of eutrophication within institutions, throughout the country.

And acknowledging whereas:

(1) Anthropogenic eutrophication is reversible – there are no quick fixes and long-term, sustainable and lasting solutions are necessary; and

(2) Engineered and technical interventions will not fully solve all eutrophication-related problems – social and economic trade-offs are necessary; and

(3) All water uses should only be allowed in terms of the NWA (36:1998) – the cumulative impact of land and water use activities need to be addressed in a catchment context; and

(4) Eutrophication problems mostly do not occur in isolation from other water quality issues – eutrophication management should be undertaken in the context of integrated water quality management; and

(5) Data and information gaps exist – monitoring[90], research, reporting and transparency are pre-requisites to effective decision-making and policy implementation; and

(6) Eutrophication management requires government cooperation, vertically, between spheres of government and, horizontally, between government departments; and

(7) Government, private sector and civil society collaboration is essential – the DWS has a lead role to play with respect to eutrophication management.

Therefore:

(1) As trustee of the country's water resources, and in conjunction with all applicable legislation, including the NWA (36:1998), the WSA (108:1997) and the NEMA (107:1998), and in collaboration with government, private sector and civil society, the DWS wishes to emphasise the following intentions and policy commitments with respect to eutrophication management, country-wide:

POLICY STATEMENT 1

3.1 Application of management instruments for environmental compliance in eutrophication management

Premise

There are four broad universally accepted categories of management instruments for environmental compliance, *viz.*:

- Command-and-control[26], or regulatory, management instruments;

- Economic[45], or market-based, management instruments;
- Self-regulatory[133] management instruments; and
- Societal participation[105] management instruments.

Each of these instruments is vital to the management of water quality; specifically, also eutrophication.

Application of the management instruments

In order to limit anthropogenic eutrophication, joint and separate application of these management instruments must facilitate the aims of the Mitigation Hierarchy for decision-making on eutrophication. [33] To advance eutrophication management – there is a need to align, improve and strengthen these instruments, as well as to ensure that these instruments for compliance are effectively and consistently being supported and/or applied. The availability of suitable data and information[34] is a prerequisite.

Command-and-control, or regulatory, management instruments

The direct regulation of land and water use constitutes an inseparable part of environmental and water resource management, and will continue to play a key role in eutrophication management. There is a pressing need to shape command-and-control[26] approaches to effectively address anthropogenic point and diffuse sources of nutrient-laden water pollution[155] in order to consistently realise the Eutrophication Management Goal. However, when pursuing this goal, the constitutional need for ecologically sustainable social development and economic growth must also be acknowledged. Cooperative regulation,[35] vertically between spheres of government and, horizontally between government departments, must be pursued and strengthened, since more than one regulatory mandate influences the control of anthropogenic eutrophication. The One Environmental System and its objective to synchronise the overall process for the issuing of environmental authorisations within the prescribed period, is supported.

Examples of command-and-control instruments include environmental authorisation following Environmental Impact Assessments (EIAs)[52], water use authorisation, Environmental Management Programme Reports (EMPRs), compiled by mines, atmospheric emission licensing, waste management licensing, the control of land and water use activities through regulations, prohibition of activities to protect water resources, or instream or riparian habitat, land use development planning mechanisms and others.

Economic, or market-based, management instruments

Economic instruments[45] for eutrophication management complement the traditional command-and-control approaches and must incentivise positive behavioural change; promote the avoidance, prevention and minimisation of excessive nutrient-loading; stimulate innovation; tackle anthropogenic eutrophication priorities, relating to both point and diffuse pollution sources; promote economic efficiency; and raise revenue for, among other things, eutrophication management related expenditures. External cost caused by

[33] Refer to **POLICY STATEMENT 2**: The Mitigation Hierarchy for decision-making on eutrophication.

[34] Refer to **POLICY STATEMENT 12**: Monitoring.

[35] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

anthropogenic eutrophication must, where appropriate, be internalised, considering economic incentive-based regulation[36] to limit nutrient-loading.

Examples of economic instruments include the WDCS.

Self-regulatory management instruments

Self-regulation[133] is well-suited to promote both corporate responsibility – which means selecting particular production methods, processes and waste streams that will have the least impact on water resources (*i.e., "environmental morals"*), and corporate accountability – which means ensuring that products and operations do not violate prescribed norms, standards and laws (*i.e., "legal compliance"*).

Self-regulation supports command-and-control, or direct regulation, and lessens pressure on Government resources, specifically with respect to regulatory compliance monitoring[27] and enforcement[50]. Schemes promoting responsible self-regulation must be investigated, supported and encouraged.

Examples of self-regulatory instruments include ISO 14001 [ISO, 2015], voluntary standards for the certification of production processes, such as Global G.A.P. (Good Agricultural Practice) and others.

Societal participation management instruments

Partnerships with civil society must be employed, alongside traditional governmental mechanisms, for increased decentralised and participatory management[37] and to promote an increasingly participatory, bottom-up method of governing anthropogenic eutrophication. Societal participations for eutrophication management must be voluntary and based on shared responsibility; complement, rather than substitute, governmental strategies; preferably consist of a range of multi-level stakeholders; ensure transparency and accountability; produce tangible results; be adequately funded; and integrate with the application of other eutrophication management instruments. Societal participation provides a good platform for non-economic incentive-based regulation[38] to facilitate a reduction of nutrient-loading.

Examples of societal participation instruments include Catchment Management Forums (CMFs), citizen-based monitoring and reporting on compliance to water quality standards and objectives.

Policy status

Although the application of the management instruments for environmental compliance is not novel, the formalised requirement for the synchronized application of the individual management instruments in eutrophication management, to achieve common goals and policy objectives, is. This is a new policy statement.

[36] Refer to **POLICY STATEMENT 7**: Incentive-based regulation.

[37] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

[38] Refer to **POLICY STATEMENT 7**: Incentive-based regulation.

POLICY STATEMENT 2

3.2 The Mitigation Hierarchy for decision-making on eutrophication

Premise

In any situation where several policies determine management goals, it is important to establish priorities.

Mitigation Hierarchy for decision-making

To ensure consistency in reaching and implementing management decisions, a mitigation hierarchy for decision-making on eutrophication applies. This hierarchy for decision-making reflects present government policy and requires the following mitigation options to be considered sequentially in a hierarchy of increasing risk:

- Anthropogenic nutrient-loading and excessive primary production, *inter alia* causing degradation of aquatic ecosystems and adverse impacts on society and the economy, **must be avoided and prevented**!
- Or, where anthropogenic nutrient-loading and excessive primary production, *inter alia* causing degradation of aquatic ecosystems and socio-economic impacts, cannot be altogether avoided and prevented, **are minimised**!
- Or, where undue anthropogenic nutrient-loading and excessive primary production, *inter alia* causing degradation of aquatic ecosystems and socio-economic impacts, have occurred, **are remedied**!
- Or, where anthropogenic nutrient-loading and excessive primary production, *inter alia* causing degradation of aquatic ecosystems and socio-economic impacts, cannot be altogether avoided and prevented, or sufficiently minimised or remedied, **are offset elsewhere!**

Most importantly – the Mitigation Hierarchy for decision-making on eutrophication (**FIGURE 32**) must always be considered within a catchment context by pursuing both the Differentiated[39] and Receiving Water Quality Objectives[40] Approaches, by opting for the Best Practicable Environmental Option (BPEO)[41] and by applying the Precautionary Principle,[42] as stipulated in the policy.

Avoidance and prevention of anthropogenic eutrophication

Irrespective of the amount of allocatable water quality[3] – water users[160] must be strongly encourage to avoid and prevent all anthropogenic nutrient-loading[102] of receiving water resources, whenever possible. This will be effected by pursuing the BPEO.[43]

Striving for a *"zero effluent"* state, in the case of effluent[48] producing water users, should always be co-considered with the need to reconcile downstream water demand with water supply.

Pollution avoidance and prevention, in particular, applies to controlling the handling and prohibition of discharges or disposal of hazardous substances.

[39] Refer to **POLICY STATEMENT 3**: The Differentiated Approach for the control of excessive nutrient-loading.
[40] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives Approach applied to eutrophication management.
[41] Refer to **POLICY STATEMENT 9**: The application of the Best Practicable Environmental Option.
[42] Refer to **POLICY STATEMENT 4**: The application of the Precautionary Principle.
[43] Refer to **POLICY STATEMENT 9**: The application of the Best Practicable Environmental Option.

Toxicity, persistence, capacity for bioaccumulation and emerging pollutants, such as those that can cause endocrine disruption, present a major threat in receiving water resources. Where these hazardous substances are involved, both the Differentiated and the Receiving Water Quality Objectives Approaches do not readily apply, because of the fact that very little to no allocatable water quality exists and due to the difficulties associated with determining appropriate RQOs for hazardous pollutants. In the case of hazardous substances, all decisions must be based on the Precautionary Principle[114].

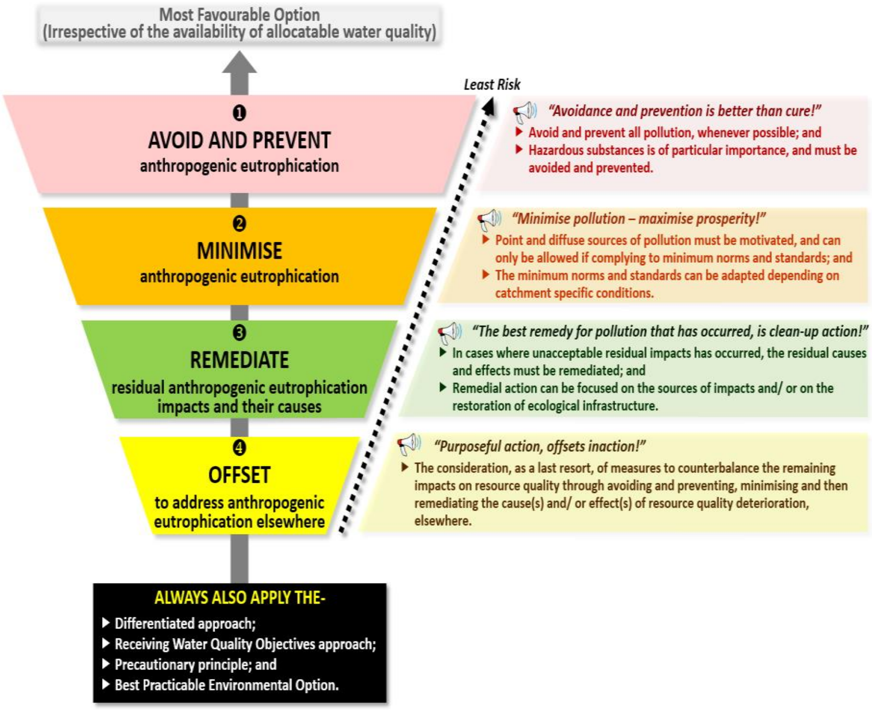


FIGURE 32: The Mitigation Hierarchy for decision-making on eutrophication.

Minimisation of anthropogenic eutrophication

It is acknowledged that, in many instances, some degradation of water quality in receiving water resources is inevitable and is sometimes necessary to permit much needed socio-economic development. Irrespective of the amount of allocatable water quality – minimisation of anthropogenic nutrient-loading, and water conservation and water demand management by pursuing the BPEO, will be encouraged at all times.

In the case of point sources, such as waste discharges, the Precautionary Principle will be applied by enforcing national minimum norms and standards, such as uniform Waste Discharge Standards (WDSs),[44] by default, should they exist. These norms and standards can be made stricter or relaxed in accordance with the Differentiated and Receiving Water Quality Objectives Approaches. When diffuse pollution sources are persistently contributing towards excessive nutrient enrichment in receiving water resources, the DWS will approach the responsible authority, examine the causes of the

[44] Currently the General and Special Standards and the Special Standards for phosphate [GN R.991, 1984].

problem and identify appropriate interventions to correct the problem and minimise anthropogenic eutrophication.

Remediation of residual anthropogenic eutrophication impacts and their causes

In cases where anthropogenic nutrient-loading has occurred and has caused unacceptable residual impacts, the cause(s) of such impact(s) and/or the affected water resource(s) must be remediated to a near-natural, or an agreed state, especially in catchments with existing water quality stress, and where remediation[121] is considered necessary, practical and equitable. It is recognised that remediation can be extremely expensive and may sometimes be totally impractical, for example in the case of some aquifers. This is regarded as a strong motivation for avoiding the need for remediation in the first place, by applying pollution avoidance and prevention and waste minimisation.

The Polluter-Pays Principle will be applied to all remediation. Where polluters cannot be held accountable, the cost of remediation has to be borne by Government.

Offsetting to address anthropogenic eutrophication elsewhere

In special cases – environmental offsetting[53] may be considered to limit, and progressively reverse the unacceptable effects of anthropogenic eutrophication. This is done through counterbalancing the effects of anthropogenic eutrophication on water resources that remain after every effort has been made to avoid and prevent, minimise and then remediate the causes/ effects, through avoiding and preventing, minimising and then remediating such causes/ effects, elsewhere. Environmental offsetting includes the process of quantifying causes/ effects in order to draw comparisons with potential offsets and to ensure that a net gain of allocatable water quality is achieved. The responsible authority must keep a publicly accessible register of all offsets to facilitate compliance monitoring. The water quality allocation plan constitutes a key tool for the implementation of nutrient-loading off-sets in South Africa.[45] The umbrella Environmental Offset Policy [DEFF, 2018] requires the DWS to compile and publish specific sector offset policies for wetlands and water quality to enable the rolling out of offsetting for eutrophication management.

Policy status

The first version of policy that addressed hierarchal decision-making to mitigate environmental degradation, in South Africa, was pioneered for water pollution.[46] Over time, this policy position was adopted as a general requirement for sustainable development and has been incorporated in South Africa's environmental legislation to limit degradation of aquatic ecosystems and biological diversity; pollution and environmental degradation; the disturbance of landscapes and natural heritage sites; waste; and impacts on people's environmental rights. In recent developments, this policy on hierarchal decision-making to mitigate environmental degradation was extended to include off-setting as an accepted concept and consideration for environmental preservation and management. The current version of the mitigation hierarchy for decision-making on eutrophication management includes these requirements.

[45] Refer to **Section 3.1.2.4.3, Part 3:** Reconciliation and allocation of water quality.

[46] Refer to IWQM Policy Statement B.2-1: The hierarchy of pollution management decision-making, [DWS, 2017b].

POLICY STATEMENT 3

3.3 The Differentiated Approach for the control of excessive nutrient-loading

Premise

A one-size-fits-all approach ignores local differential requirements for either stricter levels of protection, or more lenient approaches that are beneficial to social development and economic growth.

Differentiated Approach

The Differentiated Approach[37] ensures that catchment-specific conditions are considered when controlling sources of water pollution. Effect must be given to any Water Resource Class(es) (and RQOs/ Reserves[122]), in order to protect significant water resources against point and diffuse sources of, *inter alia* anthropogenic nutrient-loading, at a cost acceptable to society.

In cases where a particular impact is unavoidable or cannot be prevented in catchments with no water quality stress, even if considerable allocatable water quality exists, the Precautionary Principle [47] will be applied by enforcing, particularly in respect of point wastewater[151] discharges, minimum norms and standards, such as uniform Waste Discharge Standards (WDSs).[48]

In unstressed catchments, these norms and standards may be relaxed under special circumstances, but only if the Water Resource Class(es) (and RQOs/ Reserves) will be maintained, also acknowledging that the solution to pollution is never to relax applicable norms and standards for compliance's sake! Exemptions from compliance with the WDSs will be considered only as a last resort on a temporary basis and only if receiving surface water resources have enough dilution capacity to accommodate additional waste loading without affecting their fitness-for-use. Relaxations would have to be justified on the basis of technological, economic and socio-political considerations.

In stressed catchments, or catchments where the application of minimum norms and standards is insufficient to maintain the Water Resource Class(es) (and RQOs/ Reserves), stricter norms and standards, particularly in respect of point wastewater discharges, must be considered. In special cases it may be necessary to impose additional regulatory measures and/or to prohibit unsustainable practices, in order to comply with the Water Resource Class(es) (and RQOs/ Reserves).

Stricter or more lenient WDSs will be site-specific and must be based on the results of waste load allocation investigations, in accordance with the Receiving Water Quality Objectives Approach.[49] In cases where the Water Resource Class(es) (and RQOs/ Reserves) are too lenient, too strict, or require

[47] Refer to **POLICY STATEMENT 4**: The application of the Precautionary Principle.

[48] Currently the General and Special Standards and the Special Standards for phosphate [GN R.991, 1984].

[49] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives Approach applied to eutrophication management.

adjustment, reclassification and/or the re-determination of RQOs/ Reserves may be considered.[50]

Groundwater

The South African situation, of widespread and highly localised groundwater occurrence and use, makes it physically and economically impossible to protect all groundwater resources to the same degree. Neither does policy aim to prevent impacts on water resources at all costs, since such an approach will deny much-needed social development and economic growth.

For effective and focused intervention, a differentiated approach to groundwater protection is necessary, based on the vulnerability, connectedness to other water resources and the local and regional importance of aquifers. Importance will be based on the potential yield, as well as on the level to which communities depend on the aquifer. Aquifers that represent the sole source of water for communities will be afforded special status, irrespective of the potential yield and will enjoy the highest level of protection [adapted from DWAF, 2000].

Noting the many uncertainties in managing this typically invisible water resource, the existence of environmental risk in the absence of proof to the contrary, must be presumed. It places the onus of establishing the absence of environmental harm upon the source of risk. In situations where a scientific uncertainty exists as to whether an activity could have an adverse effect, the Precautionary Principle[51] must be applied.

Resilience

The ability of water resources to assimilate waste, specifically nutrients, may not be compromised. This threshold, for water quality, is defined by water quality goals,[52] such as the Water Resource Class(es) (and RQOs/ Reserves). In cases where this threshold has been compromised, affected water resources must be remediated without delay. If the water resource, for whatever reason, cannot be remediated, offsetting, with special motivation, may be considered as a last resort.

Policy status

The discriminatory application of environmental measures to suit local or regional requirements for environmental preservation and protection is not a new policy concept. This policy position has been included because of its importance to eutrophication management and because it should be implemented in conjunction with the Mitigation Hierarchy for decision-making on eutrophication. This policy statement was derived from existing policy.[53]

[50] The NWA (36:1998), at the moment, does not make explicit provision for the reclassification of water resources or the re-determination of RQOs/ Reserves and a legislative amendment will be required. Refer to **Annexure H** for a list of all recommended legislative amendments.

[51] Refer to **POLICY STATEMENT 4:** The application of the Precautionary Principle.

[52] Refer to **Section 3.1.2.3, Part 3**: Goal setting..

[53] Refer to IWQM Policy Statement B.2-4: Differentiated water use authorisations, [DWS, 2017b].

POLICY STATEMENT 4

3.4 The application of the Precautionary Principle

Premise

The Precautionary Principle applies when there is a lack of scientific certainty regarding impacts, or when there is an unacceptable risk to human health or ecological integrity.

Precautionary Principle

In a eutrophication management context, the Precautionary Principle applies specifically-

- when WDSs for the management and control of point wastewater discharges are being determined in the absence of sufficient scientific certainty, linked to the maintenance of the Water Resource Class(es) (and RQOs/ Reserves). A lack of scientific certainty specifically exists in cases where catchment specific water quality load-based information is not readily available to inform and support the determination of *"end-of-pipe"* WDSs;
- when best practices and interventions for the management and control of diffuse sources of impacts on water resources are being determined in the absence of sufficient scientific certainty, linked to the maintenance of the Water Resource Class(es) (and RQOs/ Reserves). A lack of scientific certainty specifically exists in cases where catchment specific water quality load-based information is not readily available to support the determination of appropriate interventions to address the effects associated with diffuse sources of anthropogenic nutrient-loading[102];
- to all groundwater, assumed to be vulnerable to damage unless it can be shown otherwise;
- to the prohibiting of hazardous substances;
- to scenarios where an action taken in terms of any given policy has an unintended or perverse outcome that negate the aims of another policy. Under such a scenario, the most restrictive approach [54] must be considered for application; and
- when water resource and catchment management decisions (with an unacceptable risk profile) must be made in the absence of sufficient scientific certainty.

Under such circumstances, application of the Precautionary Principle ensures that risk-averse and conservative decisions are made to minimise risks, in support of ecologically sustainable development.

Policy status

Policy on the application of a risk-averse and cautious approach, which takes into account the limits of current knowledge about the consequences of management decisions and actions, has been included because of its importance to eutrophication management and because of the important role that this principle plays in many other pertinent eutrophication

[54] An example would be fertilizer subsidies that negate good land management practices which should be reviewed to limit over-fertilization, benefiting both the farmer for whom the cost is an *"up-front"* charge and the environment into which the excess fertilizer is discharged. [Pers. coms. Thornton, 2021].

management policy statements. This policy statement was derived from existing policy.[55]

POLICY STATEMENT 5

3.5 The Receiving Water Quality Objectives Approach applied to eutrophication management

Premise

Upstream sources of impacts, occurring as either point or diffuse sources of anthropogenic nutrient-loading, must be considered on a cumulative basis and must be controlled such that receiving water resources remain fit-for-use and that the Water Resource Class(es) (and RQOs/ Reserves), as determined for all significant water resources, are maintained. Nutrient load investigations must be carried out and used to integrate receiving water resources requirements with WDSs and to inform fitting SDCs.

Assimilative capacity

The term *"assimilative capacity"*[8] refers to the capacity of a water resource to assimilate disposed waste, through processes such as dilution, dispersion, and chemical and biological degradation, without water quality changing to the extent that fitness-for-use or ecosystem[46] health is adversely impaired [DWAF, 1995]. Importantly, the assimilative capacity of a water resource depends on many factors – including chemical processes (*e.g.,* adsorption), physical processes (*e.g.,* aeration and sedimentation) and biological processes (*e.g.,* uptake by plants and micro-organisms). These processes can vary considerably in terms of their temporal extent. *"Assimilation"* can occur by processes such as dilution, adsorption, degradation or metabolism to other (either less or more harmful) products, physical removal (*e.g.,* via volatilisation) and biological absorption and transformation (*e.g.,* bioaccumulation) [Roux , et al., 1999].

Groundwater

Good quality groundwater and interflow support base-flow and the assimilative capacity of many freshwater[62] systems. Groundwater will be protected by applying the Precautionary Principle.[56] All groundwater will be assumed to not have any assimilative capacity and to be vulnerable to damage unless it can be shown otherwise. This approach, towards the protection of groundwater, will be implemented through all source[136], resource[123] and remediation[121] directed measures and controls [DWAF, 2000].

Dilution capacity

The accurate quantification of assimilative capacity in a way that allows it to be used as a useful management instrument is an extremely complicated process. While the existence of the general phenomenon of assimilative capacity is acknowledged, it is Departmental policy to use this as a routine management instrument only in the particular context of dilution capacity. This will specifically be related to the concept of *"allocatable water quality"* (**FIGURE 33**).

[55] Refer to IWQM Policy Statement B.1-4: Targeted, risk-based approaches, [DWS, 2017b].

[56] Refer to **POLICY STATEMENT 4**: The application of the Precautionary Principle.

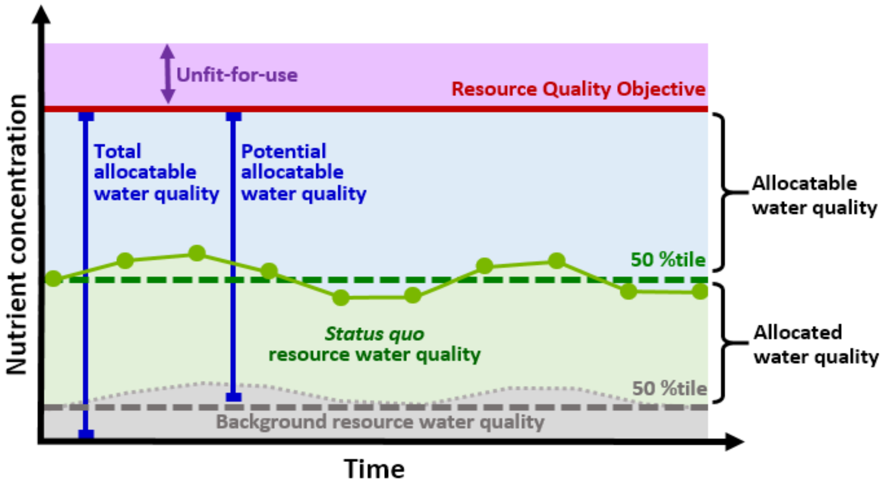


FIGURE 33: Simple conceptual illustration of allocatable water quality for an unstressed water resource.

Dilution

Dilution relates to the mixing of waters such that the resultant mixed water is of a quality that meets the Water Resource Class(es) (and RQOs/ Reserves) requirements. Dilution can take place prior to discharge, or in a receiving water resource downstream of a *"mixing zone"*.

Allocatable water quality

Understanding the basic concept of allocatable water quality is complicated by the many water quality attributes that may be involved. In general, each type of user in a catchment may require each of a number of attributes to fall within some pre-determined range for that water to be considered *"fit-for-use"*. These attributes may vary from concentrations or loads of chemical substances, to biological responses (such as toxicity), and measures of physical pollution.

For water to be judged *"fit-for-use"* for a number of different water users in the same catchment, the water quality needs to satisfy the most demanding of those water users.

Just as a quantity of water can be *"used"*, so can water quality. Typically, this will be quantified in terms of individual water quality attributes. This is the basis for the concept of *"allocatable water quality"*, which can be defined from two points of view:

- First, it can be regarded as that water quality, if any, that remains allocatable (available) to uses other than the strategic national priority uses (Reserve, international obligations, etc.) and current ELUs; and
- Secondly, it can also be more formally regarded as the maximum worsening change in any water quality attribute away from its present value, which will still maintain it within a pre-determined range that reflects the desired future state, typically defined by RQOs. If the present state is outside of the pre-determined range, the allocatable water quality is zero.

A water resource will be considered *"stressed"* in respect of a water quality attribute if, for that attribute, there is no allocatable water quality [DWAF, 2006b].

Allocatable water quality can be estimated using a Total Maximum Daily Load (TMDL)[143] approach wherein a specific water quality goal is modelled to determine the maximum level of a contaminant that can be discharged without degrading the receiving water resource.

The Department is under no obligation to fully allocate all the allocatable water quality that may exist in any particular water resource. In fact, care must be taken to implement the Receiving Water Quality Objectives Approach in conjunction with the Mitigation Hierarchy for decision-making[57] – this being necessary to prevent water resources from deteriorating to the point where all water resources eventually become only marginally fit-for-use.

Policy status

The Receiving Water Quality Objectives Approach[119] existed since 1991 [DWAF, 1991]. The explicit expression of this approach through source directed measures and controls, however, remains to be fully implemented. The application of appropriate source directed measures and controls in eutrophication management is essential, justifying the inclusion of the particular policy statement as part of pertinent eutrophication policy. This policy statement was derived from existing policy.[58]

POLICY STATEMENT 6

3.6 A life cycle view on nutrient-loading

Premise

A life cycle view (**FIGURE 34**) on the origin and fate of nutrients has become inevitable. Life Cycle Assessments (LCA)[78] of many household products has demonstrated that the impact of detergent phosphorus[107] on WwTWs' phosphate loading varies significantly between facilities, depending on the contribution made by industrial sources in the facility's catchment, but may be up to 50% Soluble Reactive Phosphorus (SRP) and 32% Total Phosphorus (TP) in WwTWs treating predominantly residential wastewater [Quayle, et al., 2010; Pillay & Buckley, 2001].

Life Cycle Assessment

LCA provides an extension of the notion to *"treat causes, rather than their symptoms"*, which is based on the general observation that such an approach is typically the most cost-effective and just option. Manufacturers of products that contribute towards excessive nutrient-loading and anthropogenic eutrophication can be compared to dischargers of effluent – in this case *"discharging"* their products through their consumers to receiving water resources. The LCA approach to understand and manage the origin and fate of nutrients in household products requires further investigation in collaboration with industry. The production of nutrient-free or low nutrient content products can be enforced by regulation or can be introduced on a voluntary basis by *inter alia* utilising eco-labelling[59] and public awareness schemes and/or through encouraging the application of the ISO 14040 series

[57] Refer to **POLICY STATEMENT 2**: The Mitigation Hierarchy for decision-making on eutrophication.

[58] Refer to IWQM Policy Statement B.2-1: The hierarchy of pollution management decision-making, [DWS, 2017b], which mentions the Receiving Water Quality Objectives approach.

[59] Refer to **POLICY STATEMENT 7**: Incentive-based regulation.

of standards [ISO, 2006], which provide standards for quantitative assessment methodologies for LCA, to promote the production and use of water resource-friendly products. Most food stuff will probably be excluded from such a nutrient-limiting drive.

It will be expected of producers of such household products, in consultation with responsible authorities, to-

- compile inventories of relevant nutrient inputs in production processes and associated environmental emissions;
- evaluate potential impacts on water resources, associated with the identified nutrient inputs and emissions;
- interpret the results to enable informed decision-making; and
- give effect to the Mitigation Hierarchy for decision-making on eutrophication,[60] by limiting the amount of nutrients being passed on through the LCA *"gate"* (**FIGURE 34**).

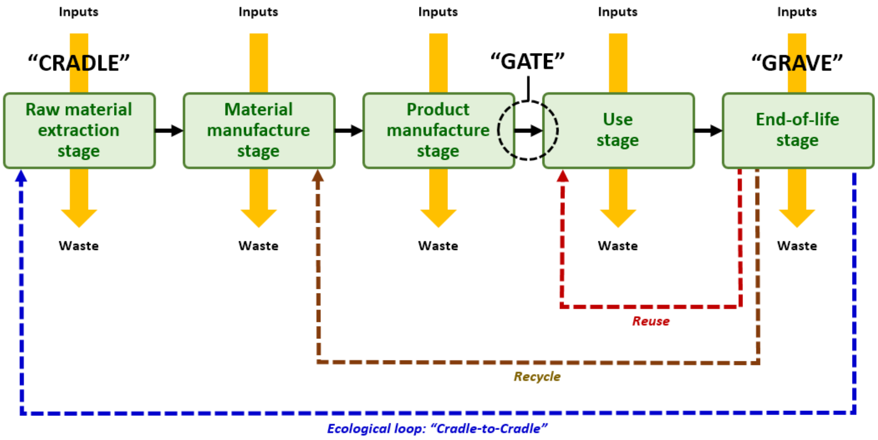


FIGURE 34: An illustration of the Life Cycle Assessment stages [US EPA, 2006].

Policy status

Whereas LCA, as an instrument of environmental analysis, has been in existence for some time now, the inclusion of a policy position to maintain a life cycle view on nutrient-loading, is new. Further investigation and the implementation of this approach will testify to the feasibility of potentially extending this approach, in future, to other pollutants. This is a new policy statement.

60 Refer to **POLICY STATEMENT 2**: The Mitigation Hierarchy for decision-making on eutrophication.

POLICY STATEMENT 7

3.7 Incentive-based regulation

Premise

Albeit that incentive-based water regulation can take several forms, examples of this type of regulation can generally be arranged into two different categories, *viz.* economic and non-economic incentive-based regulation.

Economic water incentives are based on the user-pays[147] and/or polluter-pays[113] principles and rely on market forces and changes in relative prices to modify the behaviour of water users and polluters in ways that support water resource protection or improvement, whereas non-economic water incentives are generally based on the aspiration to receive a non-monetary reward, such as positive recognition or a boosted public image.

Incentive-based regulation to limit anthropogenic eutrophication

Examples of incentive-based regulation are listed in **TABLE 13**. These options for incentive-based regulation must be considered and utilised in eutrophication management to facilitate the Mitigation Hierarchy for decision-making on eutrophication.[61]

TABLE 13: Examples of incentive-based regulation.

ECONOMIC INCENTIVE-BASED REGULATION	NON-ECONOMIC INCENTIVE-BASED REGULATION
▶ The application of subsidies, and similar transfers; ▶ Tax abatements; ▶ Taxes, fees or charges, *e.g.*, as applied through the Waste Discharge Charge System (WDCS); ▶ Deposit-refund systems; ▶ Tradable licences; and ▶ Administrative penalties.	▶ Certification schemes, such as Green Drop certification; ▶ Water Polluter Register; ▶ Management-by-shame; and ▶ Eco-labelling.

Any, or any combination, of the management instruments for environmental compliance,[62] can be utilised to promote incentive-based regulation of anthropogenic eutrophication.

Economic incentives to reward responsible behaviour

The range of economic incentive-based regulatory instruments, listed in **TABLE 13**, provides a flexible and potentially cost-effective means for attaining eutrophication management policy imperatives. Audited nutrient-loading credentials for integrated land and water resources management can be utilised to reward responsible behaviour.

[61] Refer to **POLICY STATEMENT 2**: The Mitigation Hierarchy for decision-making on eutrophication.

[62] Refer to **POLICY STATEMENT 1**: Application of management instruments for environmental compliance in eutrophication management.

However, subsidies and other forms of support measures may also distort prices, affect resource allocation decisions and change the amount of goods or services produced, distributed and consumed in an economy in a way which can be damaging to water resources. For example, subsidies on agricultural products can lead to overuse of fertilisers and eutrophication.

Payments for improving ecosystem services at the catchment-scale

Innovative approaches to ecosystem service provision include *"payments for improving ecosystem services at the catchment-scale"*, the application of which encourages downstream users to provide financial or other incentives to upstream communities to engage in land management practices that benefit the downstream users [Lin & Thornton, 2014]. Examples include subsidies to upstream farming communities to employ buffer strips adjacent to river courses to improve downstream water quality, or to employ potentially more costly drip irrigation practices to preserve stream flow that provides water to a downstream municipality. Application of such arrangements typically requires an "honest broker" (agency or nongovernmental entity) that acts as an intermediary between participants and ensures timely payments and monitors performance of the contracting parties. In South Africa, Water Management Agencies potentially could perform this role.

Economic incentive-based regulation and the User-Pays Principle

The User-Pays Principle is a pricing approach based on the idea that the most efficient allocation of resources occurs when consumers pay the full cost, or a part thereof, of the *"goods"* that they consume. To solve anthropogenic eutrophication and development challenges, benefits from investments must be maximised, and economic incentives must be put in place that ensure lasting systematic change and reduce excessive nutrient-loading. The User-Pays Principle must be employed to incentivise the reuse[129] and recycling of wastewater that contributes to excessive nutrient-loading and anthropogenic eutrophication. The reconciliation of water supply and demand must be considered in all instances.

Economic incentive-based regulation and the Polluter-Pays Principle

The Polluter-Pays Principle seeks to reverse externalised pollution costs and to achieve accountability by ensuring that such pollution costs are internalised and carried by the polluter, with due regard to public interest and without unduly distorting trade and investment. To solve anthropogenic eutrophication and development challenges, benefits from investments must be maximised, and economic incentives must be put in place that ensure lasting systematic change and reduce excessive nutrient-loading. The Polluter-Pays Principle must be employed to limit anthropogenic nutrient-loading.

Non-economic incentive-based regulation

Water users, where feasible and desirable, must be incentivised through non-economic regulation to limit anthropogenic nutrient-loading. In this instance certification schemes, such as Green Drop Certification, has a most important role to play, not only to incentivise excellence, but also to promote transparency[63] and cooperative management.[64]

[63] Refer to **POLICY STATEMENT 13**: Information management.

[64] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

Employee performance incentives

Employee performance recognition can be combined with financial incentives and rewards and should be utilised in sectors that affect anthropogenic eutrophication, to improve the trophic status of water resources, *e.g.,* utilising Green Drop Certification scores to incentivise municipal employees.

The importance of management performance and resource quality data and information

The successful and sustainable implementation of incentive-based regulation, whether economic of non-economic in nature, is reliant on the regular availability of appropriate and reliable data and information. [65] Everyone has the right of access to information that is held by another person and that is necessary for the protection of any constitutional right [Constitution, 1996, S.32]. Therefore, incentive-based regulatory systems, such as the Green Drop System, support a constitutional obligation.

Policy status

Whereas incentive-based regulation, as a concept, has been considered for some time, with one or two examples of practical implementation, *e.g.,* the Green Drop System (GDS) and the development of the WDCS, to testify to this fact, little success in implementing or continued application of this approach was achieved. As incentive-based regulation, potentially, can provide significant benefit to eutrophication management, and in support of similar requirements in the IWQM Policy yet to be implemented, it was opted to include this particular policy statement as pertinent to eutrophication management policy. This policy statement was derived from existing policy.[66]

POLICY STATEMENT 8

3.8 Nature-based solutions

Premise

Ecological infrastructure is the nature-based equivalent of built or hard infrastructure and provides renewable (**FIGURE 35**) and non-renewable services, or *"nature-based solutions"* [Costanza, et al., 1997] to citizens, which fall into one of the following four broad categories [WRC, 2014]:

- **Supporting services,** like nutrient dispersal and cycling, seed dispersal and primary production;
- **Provisioning services**, like food (*e.g.,* fresh-water fish and game), crops, wild foods, spices, water, minerals, medicinal plants, pharmaceuticals, biochemicals, industrial products, energy (hydropower, biomass[15] fuels);
- **Regulating services**, like carbon sequestration and climate regulation, waste decomposition and detoxification, purification of water and air, crop pollination, pest and disease control; and
- **Cultural services**, like cultural, intellectual and spiritual inspiration, recreational experiences (including ecotourism) and scientific discovery.

[65] Refer to **POLICY STATEMENT 12** and **POLICY STATEMENT 14**, respectively on: Monitoring and Information management.

[66] Refer to IWQM Policy Statements B.2-7: Administrative penalties; B.2.8: Alternative instruments to incentivise responsible behaviour; and C.2-5: Implementation of the WDCS, [DWS, 2017b].

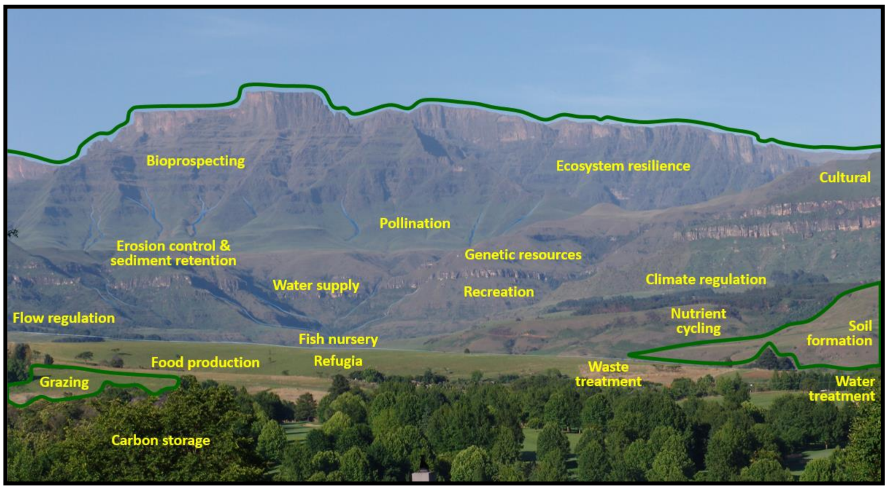


FIGURE 35: Integrated ecosystem services. Photo: © J.J. van Wyk.

Catchment services and water security

In a eutrophication context, the emphasis is on the ecological infrastructure that underpins water-related ecosystem services[47] or solutions – colloquially known as *"catchment services"*. In essence, ecological infrastructure that supports healthy catchments does much the same work as water treatment plants and other built water quality infrastructure, but without the expensive equipment and associated operating costs, and with added benefits like protection of wildlife habitats and carbon sequestration [WRC, 2014]. Additionally, maximising ecological infrastructure services and water security supports South Africa's development objectives of poverty alleviation, rural development and job creation [NPC, 2012]. In short: "*Catchment health"* equates to *"human health and well-being"* [Pers. coms. Riddell, 2021].

Ecological infrastructure associated with high yield water source areas

Of special importance is the protection of high-yield water source areas, in particular the strategic water source areas,[67] which are those areas that supply a disproportionately large amount of mean annual runoff[83] to the geographical region of interest [le Maitre, et al., 2018; Nel, et al., 2013; Colvin, et al., 2013]. These areas, thus, are suppliers of significant dilution capacity to receiving water resources and mitigate against down-stream water quality impacts by supporting the downstream capacity of water resources to assimilate waste.

Water-rich areas, scattered throughout catchments, are generally also associated with wetlands that provide valuable water quality improvement functions. Although the water quality improvement potential of the wetlands that are associated with the strategic water source areas are typically limited because they are generally located above point and diffuse impacts, the cumulative water quality improvement function of all the wetlands in a catchment together is probably significant.

[67] The NWA (36:1998) allows for only the prohibition of activities in high yield water source areas. A legislative amendment is necessary to allow for the declaration of strategic water source area as protected areas. Refer to **Annexure H** for a list of all recommended legislative amendments.

Ramsar Convention

South Africa, as a signatory of the Ramsar Convention on wetlands of international importance, must ensure that designated wetlands are conserved and utilised sustainably. Anthropogenic eutrophication, posing a major threat to wetlands, in general, must be limited and managed, especially in the case of Ramsar Wetlands, to preserve rare or unique wetland types; and to conserve biological diversity, including water birds, fish, and other taxa.

National Freshwater Ecosystem Priority Areas

Responding to the high levels of threat prevalent in river, wetland and estuary ecosystems of South Africa – Freshwater Ecosystem Priority Areas (FEPAs) were identified to meet national biological diversity goals for freshwater ecosystems and to develop a basis for enabling effective implementation of measures to protect FEPAs. These FEPAs, therefore, provide strategic spatial priorities for conserving the country's freshwater ecosystems and supporting sustainable use of water resources through the management of eutrophication and other regulatory means.

Functioning ecological infrastructure

Decision-making in eutrophication management must support the maintenance of functioning ecological infrastructure, in particular ecological infrastructure in designated special areas, such as strategic water source areas, Ramsar Wetlands and FEPAs, and, where necessary, the restoration of degraded ecological infrastructure. Ecological infrastructure must be integrated into all land use development and water resource planning and management efforts, including at the national planning and management scale. The private sector has a significant role to play in investing in ecological infrastructure as a means of managing risk; as a licence to operate; and as a custodian of ecological infrastructure.

Policy status

The utilisation of ecological infrastructure to provide nature-based solutions to eutrophication-related challenges, as a formal policy position, is new. Policy on the protection of designated areas,[68] however, exists.

POLICY STATEMENT 9

3.9 The application of the Best Practicable Environmental Option

Premise

In any project or development, several options are usually available to address eutrophication-related challenges. The recommendation for the desired option must be based on scientific defensible evidence.

Eutrophication management options and identification of the Best Practicable Environmental Option

All feasible eutrophication management options must be identified and appraised in order to identify the Best Practicable Environmental Option (BPEO)[14]. The BPEO is the option that provides the most benefit or causes the least damage to the environment as a whole, at a cost acceptable to society, in the short term, as well as in the long term [NEMA, 1998, S.2.(4)(b)].

The appraisal of options must be done, within the context of the Mitigation Hierarchy for decision-making on eutrophication, [69] by considering all

[68] Refer to IWQM Policy Statement B.2-5: Instruments for the protection of designated areas, [DWS, 2017b].

[69] Refer to **POLICY STATEMENT 2**: The Mitigation Hierarchy for decision-making on eutrophication.

relevant ecological, social and economic implications. These implications can be compared and evaluated by utilising options analysis tools, such as Cost-Benefit Analysis (CBA)[30], Life Cycle Assessment (LCA), Strategic Environmental Assessment (SEA)[138], Environmental Impact Assessment (EIA)[52], Environmental Risk Assessment (ERA)[54], Social Impact Assessment (SIA)[135] and many more. The analysis of options should be polluter-pays biased and must, additionally to the short-term planning horizon, also consider long-term residual impacts. Long-term costs should not exceed shorter-term benefit. Solutions with unwanted or unintended consequences, such as substituting point sources for diffuse sources of unabated impact; or the evaporation of water containing waste must be avoided. Options with fatal flaws may not be implemented.

All feasible project alternatives, such as project desirability, necessity, short- and long-term feasibility, location, scale, layout, technology and phasing must be considered.

BPEO appraisal

BPEO appraisal generally includes the following generic key stages, *viz.*:

- Objectives definition – including the identification of all relevant Management Class(es) (and RQOs/ Reserves) and/or any RWQOs/ WQPL that may exist;
- Options generation;
- Options analysis;
- Documentation of the results of the options analysis;
- Authorities' consultation;
- BPEO selection;
- Authorities sanction and/or authorisation;
- BPEO implementation;
- Monitoring and review; and
- Adaptively modifying the selected options for optimal results.

Best management practice

Additionally, best management practice options must always be considered in the context of the Mitigation Hierarchy for decision-making on eutrophication[70] and from a catchment management perspective,[71] and should, amongst others and where appropriate, include:

- The application of best available technology;
- Utilisation of cleaner technology and cleaner production;
- The conversion of environmental problems into socio-economic and developmental solutions;
- Waste reduction, recycling and reuse; and
- The use of buffer zones.

Operation and Maintenance (O&M) of infrastructure solutions

Infrastructure solutions include ecological[72] and built or hard infrastructure. The operation of such infrastructure solutions must support the ambitions of the *Eutrophication Management Strategy for South Africa*, specifically

[70] Refer to **POLICY STATEMENT 2**: The Mitigation Hierarchy for decision-making on eutrophication.
[71] Refer to **POLICY STATEMENT 10**: Holistic eutrophication management.
[72] Refer to **POLICY STATEMENT 8**: Nature-based solutions.

including the prevention and avoidance of anthropogenic nutrient-loading and excessive primary production, as first priority [73] and the obligation to lawfully[74] use water, as required by the NWA (1998:36).

Additionally, the maintenance of infrastructure solutions, especially in the case of build and hard infrastructure, Includes planned maintenance, repairs, refurbishment and renewal, and provisioning for replacement. Infrastructure maintenance must be included into the whole-life cycle costing of infrastructure development at the planning stage, and must be done in support of the ambitions of the *Eutrophication Management Strategy for South Africa*, as stipulated.

Policy status

Although BPEO is mentioned in other water quality management policy statements, [75] discrete water quality management policy requiring the application of the BPEO has not been published. Suitable solutions, such as addressing challenges in connection with untreated sewage spills, are vital, and must be identified and implemented. This is a new policy statement.

POLICY STATEMENT 10

3.10 Holistic eutrophication management

Premise

Effective water quality management, specifically the management of eutrophication, is not possible if being conducted on an *ad hoc* basis!

Multiple point and diffuse sources of anthropogenic nutrient-loading, potentially affecting a multitude of receiving water users and aquatic ecosystems in different ways, in any given catchment, can only be controlled and managed effectively, if such control and management efforts are well planned, coordinated and integrated from the catchment basis upward to the national strategic scale, and also from the catchment basis downward to the source specific operational scale, and *vice versa*.

Holistic catchment eutrophication management thinking deals with wholes rather than parts

Different land and water use activities occur in sub-catchments, which are nested within larger catchments, which, in some instances, may also be linked to neighbouring catchment areas via inter-basin transfers or shared groundwater resources. Water resources, furthermore, are not confined to administrative areas and are often transecting, or shared as, local, provincial, national and, occasionally, as international boundaries. Additionally, water resources that are fit-for-use are an essential requirement of socio-economic advancement in South Africa. Ecological considerations and the protection of water users need to be balanced against the needs for social development and economic growth at the various geographical and political scales mentioned. The entire water value chain – from resource to source to resource to sea needs to be considered collectively. The character of receiving water resources testifies to the nature of the upstream catchment area and its associated land and water use activities. Regulatory responsibilities to control eutrophication-related impacts are shared

[73] Refer to **POLICY STATEMENT 2**: The Mitigation Hierarchy for decision-making on eutrophication.

[74] Refer to **Section 3.2.2.2.5, Part 3**: Lawful water use.

[75] Refer to IWQM Policy Statement B.2-6: Compliance monitoring and enforcement, [DWS, 2017b].

amongst different spheres of government and between government departments. Eutrophication management, thus, is interrelated, and the focus of management varies at different geographical scales (**FIGURE 36**) – necessitating that strategic considerations inform local action.

***"Horizontal"* and *"vertical"* integration**

Whereas it is vital that *"vertical"* integration across the different scales of eutrophication management takes place, it is equally important that *"horizontal"* integration is also achieved. In the context of managing eutrophication, this, for instance, implies that any given Water Use Authorisation or Water Services Development Plan (WSDP) or Catchment Management Strategy (CMS), should not *"vertically"* contradict the National Water Resource Strategy (NWRS), neither should there be *"horizontal"* contradiction at any scale of management, for instance, incompatible authorisations, whether it be Water Use Authorisations, Environmental Management Programme Reports (EMPRs), waste management licences, or any other authorisation.

Application of the most restrictive approach

Local level plans and policies should be based upon and consistent with national policies and priorities. Actions within any given policy level should also be informed by the Precautionary Principle,[76] meaning that the most restrictive approach be applied across agencies.

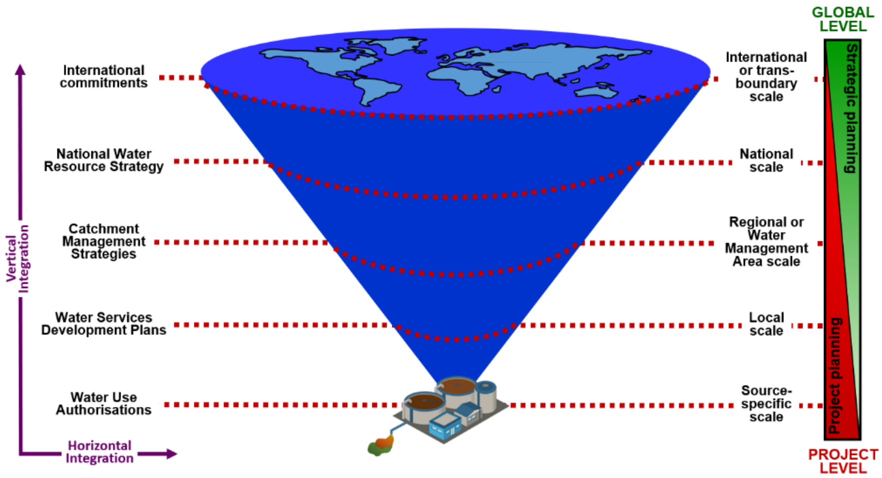


FIGURE 36: Geographical scales of eutrophication management in the context of integrated water resource management.

Tools for holistic eutrophication management

Various mechanisms exist and must be employed, in concert, to ensure that *"bigger-picture"* management of eutrophication transpires into focused local action. These mechanisms include:

- Water management strategies and services plans, supported by integrated water resource and services planning and stipulating frameworks for eutrophication management at the local, catchment and Water Management Area (WMA), national and transboundary scales, as may be relevant, must be established and implemented;
- Appropriate statutory Resource[123] Directed Measures (RDMs), *i.e.,* Water Resource Class(es) (and RQOs/ Reserves), and any other

[76] Refer to **POLICY STATEMENT 4**: The application of the Precautionary Principle.

requirements for complying with the RQOs, such as RWQOs/ WQPLs, must be determined, planned and operationalised, in accordance with the Receiving Water Quality Objectives Approach;[77]

- All the eutrophication management instruments[78] must be applied together to ensure that impacts on the water resources remain within acceptable levels; and
- Appropriate water resource and services data must be collected[79] and management information generated[80] to yield water quality intelligence necessary to facilitate informed decision-making[81] and eutrophication management.

Water and other institutions

Water Management, in particular Catchment Management Agencies (CMAs), and Services Institutions must be established, supported and strengthened to assume their designated mandates and to devolve eutrophication management to the appropriate levels so as to enable everyone to participate,[82] and to enrich management efforts with local stakeholder knowledge and insights.

The pricing of water use must be reflective of catchment eutrophication management priorities to ensure that water institutions are appropriately resourced.

Water institutions need to collaborate with other institutions that manage aspects of the environment or that manage land use activities that may potentially affect nutrient-loading and anthropogenic eutrophication.

Policy status

The many aspects to eutrophication that make it a prerequisite to view and address matters holistically. For this reason, policy on holistic eutrophication management was included. This is a new policy statement.

POLICY STATEMENT 11

3.11 Eutrophication management responsibility and accountability

Premise

Escalating anthropogenic eutrophication, and a lack of ownership by many in positions of influence, emphasise a dire need for taking responsibility and for being accountable for actions taken, or the lack thereof.

Duty of care

There is a duty of care[42] on every water user who causes, has caused or may cause significant pollution or degradation of water resources to take reasonable measures to avoid and prevent such pollution or degradation from occurring, continuing or recurring, or, in so far as such harm to water resources is authorised by law or cannot reasonably be avoided or stopped,

[77] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives Approach applied to eutrophication management.
[78] Refer to **POLICY STATEMENT 1**: Application of management instruments.
[79] Refer to **POLICY STATEMENT 12**: Monitoring.
[80] Refer to **POLICY STATEMENT 13**: Information management.
[81] Refer to **POLICY STATEMENT 14**: Water resource assessment and planning to inform decision-making.
[82] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

to minimise and rectify such pollution or degradation of water resources [NEMA, 1998, S.28(1)].

Responsibility

EVERYBODY IS RESPONSIBLE!

Furthermore, every water user has the ongoing and general *"responsibility"* to act lawfully, including to give effect to the duty of care, as paraphrased above for water resources, in this case to avoid and prevent or minimise anthropogenic eutrophication. Unlawful conduct, violating this ongoing and general *"responsibility"*, would include water use that is not permissible under the NWA (36:1998), or causing water pollution, such as diffuse wash-off from land that causes, has caused or may cause excessive primary production in receiving water resources.

Accountability

ACCOUNTABILITY IS ASSIGNED!

In contrast to *"responsibility"*, *"accountability"* is assigned, for instance, by mandate in terms of the Constitution (108:1996) and other legislation, or by water use authorisation, preferably to a single party, and for a specific activity or assignment. *"Accountability"* is about a duty to give account of (report on) the state of affairs or outcomes related to that particular activity or assignment.

In cases where the discharge of water containing waste is authorised, or where a municipality (Water Services Authority), for instance, was mandated with the provision of water services, or both, the accountability accompanying the particular mandate or water use entitlement cannot be readily passed on to a third party, unless provided for by law. Neither do actions, such as appealing for support of any kind, for instance by a water user, including by a municipality, provide immunity from obeying the law.

Liable parties and liability

There is a duty on the following parties to take all reasonable measures to prevent anthropogenic eutrophication in a water resource from occurring, continuing or recurring, if an activity or process is or was performed or undertaken on land, or any other situation exists on land which causes, has caused or is likely to cause excessive nutrient-loading of a water resource [NWA, 1998, S.19]:

- The owner of the land;
- A person in control of the land; or
- A person who occupies or uses the land.

The person who has to undertake the measures is therefore not necessarily the person who is or was responsible for the activity, process or situation. The activity or process could even have taken place before the person concerned became the owner of the land or in control of the land or occupied or used the land. Further, the water resource polluted or that could be polluted need not be on the land concerned.

The National Environmental Laws Amendment Act, 2009 (Act No. 14 of 2009) strengthened retrospective liability by explicitly stating that the duty of care also applies to significant pollution or degradation that–

- occurred before the commencement on the NEMA (107:1998) in 1998;

- arises or is likely to arise at a different time from the actual activity that caused the contamination; or
- arises through an act or activity of a person that results in a change to pre-existing contamination.

In the event of an unlawful act or where the duty of care, *viz.* to avoid and prevent or minimise anthropogenic eutrophication, is not satisfied, such a violation is likely to lead to some sort of legal action for relief. In such a scenario, the party(ies) may be legally liable and potentially guilty of an offence.[83]

Policy status

The perceived lack of responsibility and accountability is regarded to be a major part of current challenges in connection with sub-standard effluents being released and contributing towards the eutrophication of water resources. For this reason, policy on eutrophication management responsibility and accountability has been included. This is a new policy statement.

POLICY STATEMENT 12

3.12 Monitoring

Premise

A base of appropriate data and information is a vital element of effective water quality planning and management, in this instance, specifically with respect to eutrophication (**FIGURE 37**). Such data and information may relate to water quality, quantity and the integrity of aquatic ecosystems, or their causal relationships, which often extend into the socio-economic domain. Data and information must be gathered over a suitable period and at the correct spatial scale.

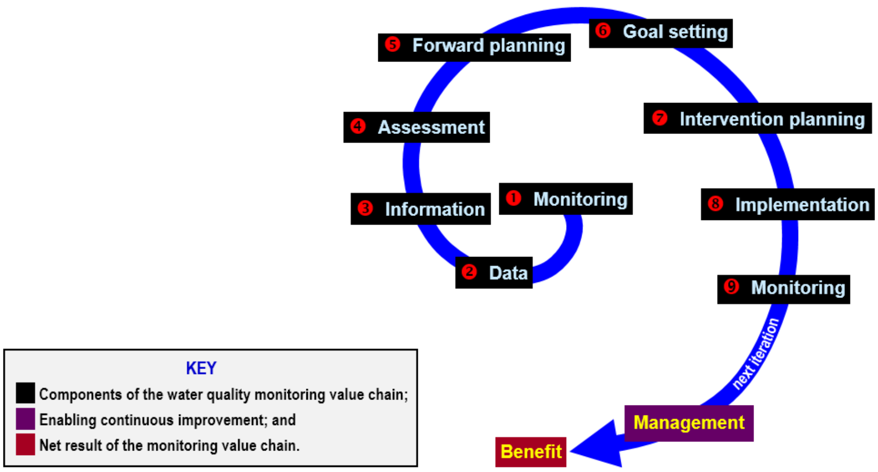


FIGURE 37: The water quality monitoring value chain [Pers. coms. Grobler, 2012].

[83] Refer to **POLICY STATEMENT 12**: Monitoring.

Purpose of eutrophication-related monitoring

Acknowledging the obligation to establish a monitoring system for water resources [NWA, 1998, Chapter 14], eutrophication-related data and information must be collected to assess-

- sources of anthropogenic eutrophication and their relative load contributions, especially in the case of point discharges – compliance with WDSs;
- the application of wastewater and waste reuse and recycling strategies;
- the status of and effects on receiving water quality, especially nutrient-loading of receiving water resources, and compliance with RDMs and RWQOs/ WQPLs;
- the integrity of aquatic ecosystems, as an indicator of system health;
- the efficacy of remediation projects;
- whether offset initiatives are yielding the agreed offset improvement impacts; and
- causal chains and linkages with the socio-economic domain, and root-causes of failure.

Additionally, eutrophication-related monitoring must-

- contribute meaningfully to efforts to facilitate ecologically sustainable development;
- reflect the ecologically interdependent nature of water resources, including the dependence on water quantity, whenever appropriate; and
- become an essential enabling component of adaptive and integrated water quality management.

Use of technology

The application of smart technology and advanced eutrophication monitoring techniques can be supported if deemed cost-effective.

Temporal extent

Sampling frequencies at monitoring stations where water quality varies considerably must be higher than at monitoring stations where variation remains relatively constant. An interval of one month between the collection of individual samples at a monitoring station is generally acceptable for characterising water quality over long time periods, whereas, for control purposes, shorter frequency sampling is necessary. If significant differences are suspected or detected, samples may have to be collected daily or on a continuous basis.

The value of sustainable, long-term monitoring and the availability of suitable historic data and information should not be underestimated, and care must be taken to continue with such data gathering exercises in the interest of continued water security.

Spatial extent

Eutrophication monitoring must be executed at appropriate spatial scales, as may be necessary, including:

- National water resource status and trends monitoring, which provides a higher-level integrated picture of overall national effectiveness;
- Regional water resource performance monitoring, which compares actual resource water quality with pre-determined RDMs (such as RQOs) and or

RWQOs/ WQPLs, providing information at the spatial and temporal scale for which such objectives have been defined; and

- Source compliance monitoring, which provides local site-specific information that is required to determine the effectiveness of source directed measures and controls.

Compliance monitoring and enforcement

A significant challenge in the management of eutrophication is weakness in enforcement of legislation and authorisation conditions under the NWA (36:1998), resulting in the externalisation of costs to communities and society. The degree to which individual water users are remaining within (*i.e.,* complying with) the conditions, as defined in their water use authorisations (*e.g.,* licences), must be measured, assessed and reported on regularly. Capacity for controlling discharges of water containing waste must be enhanced. Stringent action must be taken against the unlawful discharge of water containing waste and the unlawful disposal of waste, and to ensure compliance with authorisation conditions through combined actions, by DWS and DFFE, in particular. In this regard, the exchange of information, where necessary, will be facilitated and the use of combined compliance drives can be utilised. Environmental compliance[27] and enforcement[50] capacity must be strengthened through the appointment and capacitation of Environmental Management Inspectors (EMIs), and a policy of zero tolerance towards non-compliance, specifically excessive nutrient-loading, must be applied.

Policy status

Due to the crucial role of data and information in eutrophication management, a policy statement on monitoring was included, as part of the pertinent policy on eutrophication management. This policy statement was derived from existing policy.[84]

POLICY STATEMENT 13

3.13 Information management

Premise

The collection of data and the interpretation of trophic status[145] information are critical to all aspects of eutrophication management. Without accurate information, the correct picture of the eutrophication challenges cannot be determined, and strategy formulation and implementation could be compromised. Data and information management systems are prerequisites for the assessment of eutrophication, the magnitude of the problems and challenges.

Gathering of data and information

Data management systems must be appropriately cost-effective and able to adequately meet all the requirements of national and other regional eutrophication monitoring programmes. The goal is to provide information needed for planning purposes, decision-making, operational and strategic water resources management and the establishment of relevant infrastructure, at the local, regional and national scales.

[84] Refer to IWQM Policy Statements B.2-6: Compliance monitoring and enforcement; and D.1-1: Strengthening of national water quality monitoring networks, [DWS, 2017b].

Access to information

Acknowledging the obligation to provide access to information held by the State [Access to Information Act, 2000 (Act No. 2 of 2000)],[85] data collected in national and other regional eutrophication monitoring programmes, for which the DWS, catchment management agencies or other government institutions have responsibility, will be available, or made available upon a reasonable request for access.

Government institutions should preferably not wait for parties to request data. In cases where data, such as hydrological and chemical data, is already published (for instance on websites), such initiatives should be continued.

Use of technology

Additionally, an Application Programming Interface (API) would allow app developers to access data more easily, as required.

Data and information cost

Reasonable charges for the provision of data and information may be imposed. Role-players, however, should guard against the creation of a paywall that would discourage or disadvantage South African users, *e.g.,* schoolchildren, university students and/or pensioners.

Information management cooperation and efficiency

The accepted corporate data and information management systems must be used for all management-related data and information, associated with monitoring programmes for eutrophication. The harmonisation of monitoring systems across transboundary, national, WMA, local and the water use specific scales, in the interest of improved eutrophication management, must be investigated and supported. Collaboration with local government, specifically, on eutrophication data and information handling and management, should be strengthened and improved.

Policy status

Due to the need to generate appropriate information and due to the importance of such information to eutrophication management, a policy statement on information management was included, as part of the pertinent policy on eutrophication management. This policy statement was derived from existing policy.[86]

POLICY STATEMENT 14

3.14 Water resource assessment and planning to inform decision-making

Premise

The complexities and uncertainties associated with water resource management, specifically the management of eutrophication, and the need for a sound understanding of catchment processes and issues, must be addressed.

Holistic catchment context

It is crucial to improve one's understanding, by striving for a holistic comprehension[87] of all catchment processes and issues, based on adequate and objective observations for as far as this is possible. This should occur

[85] Hereafter referred to as AIA (2:2000).

[86] Refer to IWQM Policy Statement D.1-2: Strengthening and improvement of information management systems, [DWS, 2017b].

[87] Refer to **POLICY STATEMENT 10**: Holistic eutrophication management.

before catchment management decisions are taken that are intended to improve the current state of water resources [DWAF, 2006b].

Informed decision-making

Apart from the option to address some eutrophication knowledge gaps through theoretical or applied research,[88] water resource planning, preceded by an appropriate situation assessment, must be promoted. An assessment of the relevant issues within the geographical area in question, mostly at the level of the catchment, must inform planning activities. Data and information from monitoring,[89] assessment thereof within a catchment or water resource system context and value added through water resource planning must inform water resource management and remediation activities, and thereby enrich decision-making. In the absence of suitable management knowledge, and when an unacceptable level of risk exists, the Precautionary Principle[90] must be applied to catchment and water resource management decision-making. Appropriate water resource assessment and planning provide the base for sound eutrophication management and continuous improvement.

Policy status

Eutrophication management measures should, ideally, be informed by appropriate water resource knowledge, assessment and planning, motivating the inclusion of policy on water resource assessment and planning to inform decision-making, as part of the pertinent policy on eutrophication management. This policy statement was derived from existing policy.[91]

POLICY STATEMENT 15

3.15 Resourcing of eutrophication management

Premise

The establishment of the eutrophication management strategy constitutes an initial and important step towards improving the trophic state of many water resources. An even more important step in this eutrophication management process, is the need for empowering role-players to participate, *inter alia*, in the identification, as well as the implementation of essential eutrophication management measures.

Budget, human capital and equipment

It is the constitutional duty of all spheres of government to protect the quality of South Africa's water resources. This principle is supported by the constitutional imperative for co-operative government.

Enough capable public and/or private sector employees must be appointed or assigned with eutrophication management duties, as necessary. Sufficient budget must be allocated, and the necessary equipment procured to effectively fulfil the duties assigned to personnel with eutrophication management responsibilities.

[88] Refer to **POLICY STATEMENT 16**: Promotion of eutrophication-related research.

[89] Refer to **POLICY STATEMENT 12**: Monitoring.

[90] Refer to **POLICY STATEMENT 4**: The application of the Precautionary Principle.

[91] Refer to IWQM Policy Statements B.1-2: Strengthening of integrated water resource planning at all scales; and B.1-3: Development of integrated planning approaches at the catchment scale, [DWS, 2017b].

Policy status

Good intentions without the necessary resources will achieve little, which is the motivating for including policy on appropriately resourcing of eutrophication management, as part of the pertinent policy on eutrophication management. This is a new policy statement.

POLICY STATEMENT 16

3.16 Promotion of eutrophication-related research

Premise

The eutrophication management context is continually changing, not least, due to a growing demand for more advanced and effective, yet more affordable water treatment technology; the ever-increasing pressures associated with development, causing escalating nutrient enrichment in receiving water resources; and the potential future impacts of climate change. With the growing suite of emergent water quality issues, as well as the need for innovation in resolving more pervasive issues, ongoing Research and Development (R&D) has become critical.

National water quality research and development plan

The DWS and the WRC will play a key role in developing a national water quality R&D plan that aligns applied research priorities throughout the water value chain. This is necessary to ensure that water R&D directly contributes to the resolution of water sector challenges, specifically eutrophication-related challenges, and addresses emergent areas like the growing need for the implementation of water reuse and recycling strategies. The role of South Africa's academic institutions, and independent research organisations, will be critical in the development and roll-out of this plan.

Transfer of new and applied technologies

The DWS and the WRC, together with other sector organisations, academic institutions and others, will promote innovation and knowledge sharing to support new and appropriate technology uptake. There will be a specific focus on supporting municipalities to use appropriate and new technology and designing, developing and marketing new technology and approaches in partnerships with the private sector, civil society and the research community. In this regard, the WRC and the Department of Science and Innovation (DSI) will continue to develop and enhance the impact of the Water Technologies Demonstration Programme. This programme aims to pull together the applied R&D and commercialisation stages of the water innovation continuum, and to bridge the gap between water research and the market in order to achieve a connected water innovation system that delivers socio-economic benefits for South Africa.

Policy status

Applied research and technology development is vital to the renewal and improvement of eutrophication-related knowledge, motivating the inclusion of policy on eutrophication-related research, as part of the pertinent policy on eutrophication management. This policy statement was derived from existing policy.[92]

[92] Refer to IWQM Policy Statement D.1-5: Availability of water quality data to the public, [DWS, 2017b].

POLICY STATEMENT 17

3.17 Transparency

Premise

Eutrophication management decisions must be taken in an open and transparent manner, and access to information[93] must be provided in accordance with the law [NEMA, 1998, S.2].

Communication

Communication channels, where necessary, must be established to inform and persuade, to build relationships, and to encourage open dialogue, in the public interest, on eutrophication management related topics.

Policy status

In line with the democratic values enshrined in our Constitution (108:1996), people, as citizens, must be able to participate actively in civic life. This requirement, amongst others, rely on the availability of information. The role, and potential future roles, to be played by civil society and others with respect to eutrophication is reliant on openness and transparency.[94] For this reason, policy on transparency was included as part of the pertinent policy on eutrophication management. This policy statement was derived from existing policy.[95]

POLICY STATEMENT 18

3.18 Technical capacity to take eutrophication management action

Premise

The existence of a highly trained and competent cohort of role-players across the water sector, particularly in government departments and institutions, is essential for the management of eutrophication. There is indeed existent capacity, but this is stretched, and more needs to be done to establish the necessary role-player compliments with the necessary skills to manage eutrophication.

Community wellbeing and empowerment

Community wellbeing and empowerment must be promoted *inter alia* through the raising of environmental awareness, community-based science, utilising the expertise of retired professionals, the sharing of knowledge and experience, and other means.

Eutrophication management awareness must be raised through awareness creation campaigns in schools and in public spaces, and through community outreach programmes. This will be supported by broader awareness campaigns to encourage societal action towards an improved trophic state of water resources. Public awareness can help by changing people's perception and attitudes about eutrophication, and the importance of protecting water resources and aquatic ecosystem.

Education and training

Education and training programmes must be developed and rolled out at schools, universities and at the workplace to build environmental and water

93 Refer to **POLICY STATEMENT 13**: Information management.

94 Refer to IWQM Policy Statements D.2-1 and D.2-2: Research and innovation, [DWS, 2017b].

95 Refer to IWQM Policy Statements D.2-1 and D.2-2: Research and innovation, [DWS, 2017b].

management knowledge and capacity. Schools' and universities' programmes must build the capacity of young people prior to them entering the labour market, whereas workplace programmes must sufficiently capacitate all who play roles in eutrophication management.

Capacity building programme to develop sector capacity

The DWS will develop and drive capacity building programmes to develop sector capacity [DWS, 2017b] and will-

- continue to provide bursaries for students to study water quality related subjects at universities in order to provide a pool of qualified recruits to the State;
- lead the development of appropriate on-the-job and technical training programmes for officials from all relevant state institutions to improve the capacity of government to adequately manage water quality and to address the eutrophication challenges of the future;
- in close cooperation with other government departments, continue to strengthen the capacity across the sector with regards to regulating activities that impact upon eutrophication management. This will include interventions to strengthen inter-departmental capacity to ensure, and to enforce compliance with regulations and other legislative prescripts;
- in partnership with CMAs, strengthen the capacity of CMFs to provide local capacity for water quality management, particularly eutrophication management; and
- in partnership with DFFE, also make training available to civil society organisations, active in the water sector, to enable their informed participation in integrated water quality management processes, particularly in eutrophication management.

Attracting human resources capital

Relevant employers should set themselves up as institutions that attract suitable candidates and employees so that they can create and maintain a critical eutrophication management capacity.

Professionalization of staff in key positions in local government

DWS, in collaboration with the Department of Cooperative Governance and Traditional Affairs (CoGTA), will develop the necessary regulations to ensure the professionalization of key water services positions in Water Services Authorities to ensure that the staff responsible for the management of water and wastewater systems at municipal level have the necessary training and competencies.

Policy status

Suitable capacity is a vital component of rolling-out eutrophication management, motivating the inclusion of policy on capacity building, as part of the pertinent policy on eutrophication management. This policy statement was derived from existing policy.[96]

[96] Refer to IWQM Policy Statements D.3-1 and D.3-2: Capacity building and training, [DWS, 2017b].

POLICY STATEMENT 19

3.19 Cooperative eutrophication management

Premise

Effective eutrophication management will be improved by good co-ordination, adequate institutional arrangements, cooperative planning and synergistic approaches between basin states, the various South African government departments, spheres of government and sectors, and participation by, and with, the private sector and civil society.

Transboundary cooperation and water diplomacy

Desirous of developing close co-operation for the judicious, sustainable and co-ordinated utilisation of the resources of the shared watercourses[153] in the Southern African Development Community (SADC) Region, parties, including South Africa, in 2000 agreed to the revised SADC Protocol on Shared Watercourses. In terms of this Protocol [SADC, 2000], parties will foster closer cooperation to, *inter alia*,

- promote and facilitate the establishment of shared watercourse agreements and Shared Watercourse Institutions for the management of shared watercourses; and
- advance the sustainable, equitable and reasonable utilisation of the shared watercourses;
- promote a co-ordinated and integrated environmentally sound development and management of shared watercourses;
- promote the harmonisation and monitoring of legislation and policies for planning, development, conservation, protection of shared watercourses, and allocation of the resources thereof; and
- promote research and technology development, information exchange, capacity building, and the application of appropriate technologies in shared watercourses management.

Government-wide eutrophication management

It is the constitutional duty of all spheres of government to protect the quality of South Africa's water resources. This principle is supported by the constitutional imperative for co-operative government. Actual or potential conflicts of interest between organs of state should be resolved through the applicable conflict resolution procedures [NEMA, 1998, S.2].

Civil society and corporate business partnerships

The private sector and civil society have a crucial role to play in minimising their impacts on water resources. Water forums have been created to address water challenges, align plans and strengthen collaboration. Effective stewardships and partnerships will be built to deal with eutrophication challenges in specific priority areas, and platforms like CMFs will be used to ensure stakeholder engagement and collaboration. A strategic management approach to the eutrophication challenges requires that the DWS will need to forge highly focused, fit-for-purpose, civil society and corporate business partnerships that are relevant to the eutrophication challenge. The partnership approach dictates that polluters take cradle-to-grave [97]

[97] Refer to **POLICY STATEMENT 6**: A life cycle view on nutrient-loading.

responsibility for their products and improve self-regulatory processes to reduce the regulatory burden on the state[98] [DWS, 2017b].

Stakeholder consultation

The objective is to obtain public feedback on analysis, alternatives and/or decisions. It involves acknowledging concerns and providing feedback on how stakeholder input has influenced decision-making. Decisions must consider the interests, needs and values of all interested and affected parties, and this includes recognizing all forms of knowledge, including traditional and ordinary knowledge [NEMA, 1998, S.2].

Harmonisation of policy, strategy and legislation

DWS will lead a collaborative process to ensure alignment and inter-departmental harmonisation of policies, legislation, regulation, integrated planning, compliance monitoring and enforcement [NEMA, 1998, S.2].

Policy status

One of the most noticeable differences between the 1991 and 2017 policies for water quality management, is the leap taken towards the integration of water quality management efforts by recognising the roles of public and private sector, and civil society role-players.[99] This approach is also being applied to eutrophication management, motivating the inclusion of policy on cooperative management, as part of the pertinent policy on eutrophication management. This policy statement was derived from existing policy.[100]

[98] Refer to **POLICY STATEMENT 1**: Application of management instruments for environmental compliance in eutrophication management.
[99] Refer to **Section 4.3, Part 3**: Collaboration and management participation.
[100] Refer to IWQM Policy Statements A.1-1 to A.1-6 and A.2-1 to A.2-3: Inclusive approach to IWQM, [DWS, 2017b].

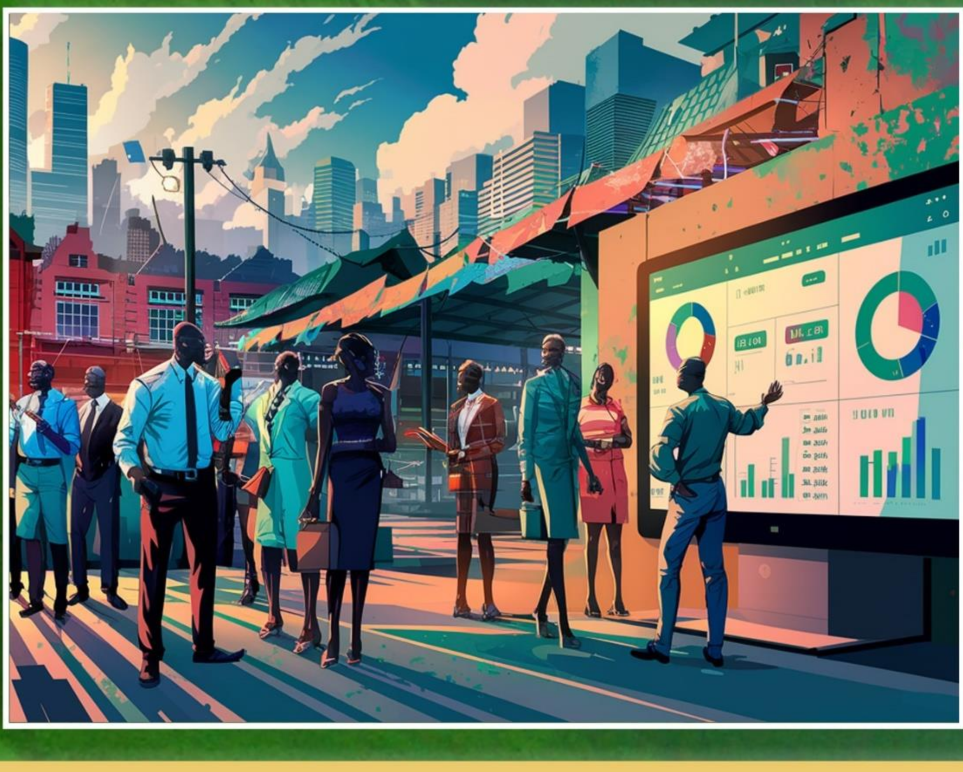
CHAPTER 4: CONCLUSION

Part 2 of the Eutrophication Management Strategy for South Africa presents a vision, mission, goal and objectives for eutrophication management, which are translated into a number of succinct policy statements that are regarded as most pertinent to eutrophication management in South Africa. These policy statements provide an extension of the over-arching IWQM Policy but focus on water quality through an *"eutrophication management lens"*. Some of the policy statements constitute extensions of the existing IWQM Policy, whereas others are new, and should be incorporated when potentially revising or updating the IWQM Policy in future. A one-page table, in **Annexure I**, provides a quick reference to the Eutrophication Management Policy, for later use.

A comprehensive approach or strategy is now required to map-out potential avenues for structured and coordinated implementation of these goals and policy imperatives for eutrophication management!

EUTROPHICATION MANAGEMENT STRATEGY FOR SOUTH AFRICA

Part 3



PART 3: EUTROPHICATION MANAGEMENT STRATEGY FOR SOUTH AFRICA

PHOTO 3: *"EVERYBODY LIVES DOWNSTREAM!"* © J.J. VAN WYK

CHAPTER 1: INTRODUCTION

In general terms, *"strategy"* maps out overarching approaches for implementation that are aimed at realising strategic imperatives - including implementing the strategic thrust of policy. This part of the document, accordingly, prescribes such overarching approaches for eutrophication management in South Africa, which, collectively, must ensure management efficacy geared towards protecting aquatic ecosystems[7] and securing water resources[158] that are fit-for-use.

The two-pronged approach opted for in this document namely, to separately define policy and strategy, makes the development of powerful and succinct strategy discussion possible. Eloquent referencing to pertinent eutrophication management policies, as well as cross-referencing to relating strategy, can simply be included, where necessary, in individual strategies.

Strategy formulation, *inter alia*, specifying authority (***"who?"***), prescribing approach and action (***"what and how?"***), and pointing to spatial (***"where?"***) and temporal (***"when?"***) scales of implementation,[101] must aim to give effect to the Eutrophication Management Goal, objectives and policy imperatives elaborated under Part 2.

Efforts, in South Africa, to manage eutrophication[58] are reliant on the adoption and execution of three types[102] of interrelated and mutually supporting strategies (**FIGURE 38**), *viz.*:

- Core strategies;
- Operational strategies; and
- Supporting strategies, for eutrophication management.

These three inter-related and mutually supporting strategies, collectively, are directed towards the realisation of the national Eutrophication Management Goal and the associated objectives,[103] as shown in **FIGURE 38**. The three types of overarching eutrophication management strategies are outlined, under

[101] The four headings, ***"Authority"***, ***"Prescribed approaches"***, "***Spatial scale of implementation***" and "***Temporal scale of implementation***", were used to structure strategy formulation throughout Part 3, and to specify "***who?***", must do "***what and how?***", "***where?***" and "***when?***".

[102] The strategy types correspond to the response groups used in the DPSIR analysis (**TABLE 1** on page 14).

[103] Refer to **Chapter 2** of **Part 2** for the visionary perspective.

Chapters 2, 3 and 4, respectively. Sectoral mandates and governance responsibilities are summarised under Chapter 5 of Part 3.

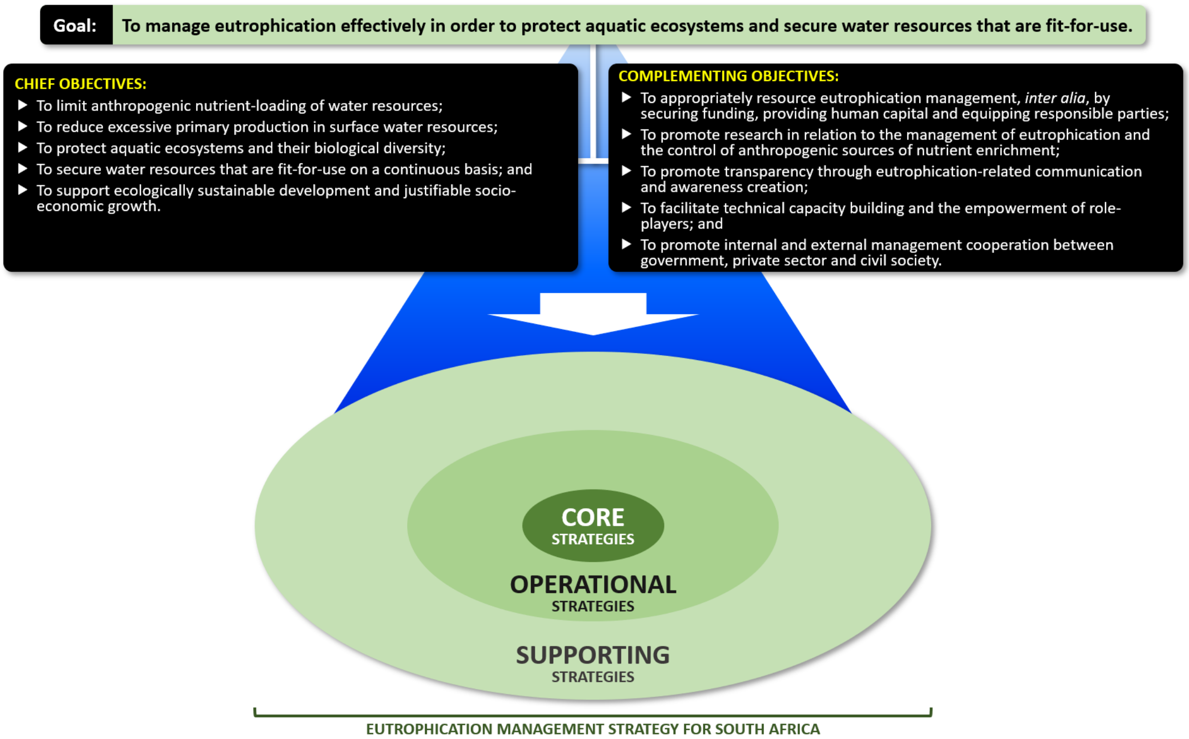


FIGURE 38: Outline of the Eutrophication Management Strategy.

An attempt was made to restrict ensuing discussions to a strategy level and to refrain from providing detailed guidelines. Some of the eutrophication management strategies, or elements thereof are unique to eutrophication management, whereas others focus on the roles of eutrophication management within the integrated management of water quality[156]. These strategies were adopted to establish a coherent framework for eutrophication management in South Africa.

CHAPTER 2: CORE STRATEGIES

The strategies, which are core to giving effect to the ambitions of the Eutrophication Management Goal and policy, are founded on the following three important requirements:

(1) The establishment of sustainable land and water use, and the strengthening of key aspects underpinning it:

Sustainable land and water use are recognised as crucial requirements for management of eutrophication. A core strategy to address current and potential future sources of excessive nutrient-loading, which are or may be caused by land and water use, is a prerequisite!

(2) The improvement of the trophic status of the country's water resources:

Intensifying land use and increasing competition for the use of the country's limited resources place increasing pressure on water resources, reduce the ability of water resources to support consumptive and non-consumptive water uses, and threaten water supply security. A core strategy to actualise fitness-for-use, and other water resource requirements; to maintain or improve the quality of water resources; and to direct appropriate levels of source control, is a prerequisite!

(3) The remediation of historic causes and effects of anthropogenic eutrophication:

Legacy sources of excessive nutrient-loading and the residual effects of excessive nutrient-loading on water resources prolong the causes and/or effects of anthropogenic[6] eutrophication. A core strategy to address remedial action and to improve residual causes and/or effects of anthropogenic eutrophication, is a prerequisite!

The core strategies for eutrophication management, therefore, are devised within an adapted management framework, comprising **Source Directed**[136], **Resource Directed**[123] and **Remediation Directed**[121] **Management** (**FIGURE 39**). Whereas Source Directed and Resource Directed Management employ measures and controls proactively, Remediation Directed Management, by its very nature, employs measures and controls reactively to address residual causes and effects.[104]

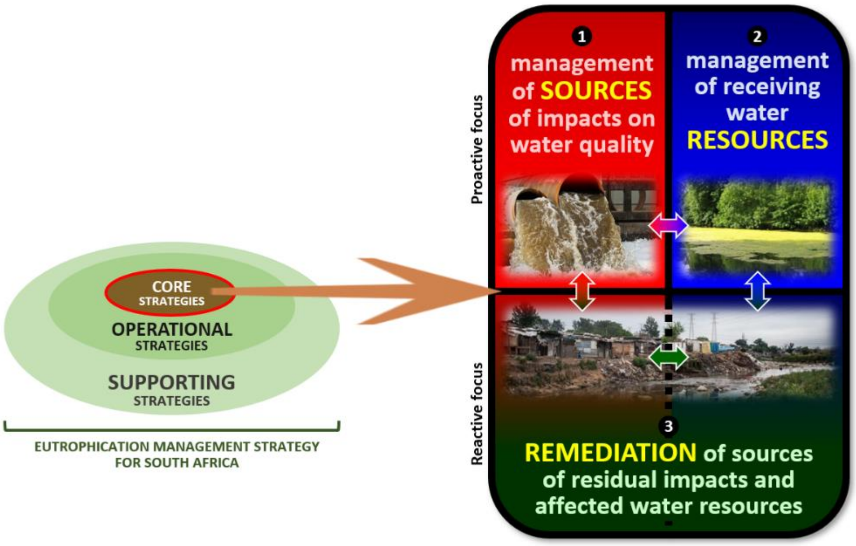


FIGURE 39: Core strategies for the management of eutrophication.

[104] Notably, such remedial actions can be focused on the remediation of both the causes (sources of impacts), as well as the effects (impacted water resources) of excessive nutrient-loading and anthropogenic eutrophication.

Each of the three core strategies are discussed next. These discussions address eutrophication management strategy conceptually and focus on the *"three unique faces"* of eutrophication management and their inter-relatedness. Due to this interrelatedness of the core strategies for eutrophication management, fragmented implementation will hamper efforts to manage eutrophication effectively, and, thus, to protect aquatic ecosystems and to secure water resources that are fit-for-use. Effective implementation of these core strategies must be pursued, and fragmented implementation must be avoided. Operational guidance, to eutrophication management, is included in the chapter following this one, *i.e.,* in Chapter 3 of Part 3, which deals with the operational strategies for eutrophication management.

2.1 Source Directed Management

2.1.1 Authority

From a eutrophication management perspective, source directed measures and controls must be imposed on land and water uses to protect aquatic ecosystems and receiving water users[160] against impacts caused by excessive nutrient-loading and anthropogenic eutrophication. Since these source directed measures and controls are not necessarily all captured within water legislation and policy, and since land use managed often is the responsibility of authorities other than the DWS, the roles of other government departments in the management of sources of anthropogenic eutrophication have to be acknowledged, in line with the need for the cooperative management of eutrophication.[105]

The relevant competencies (sectors) that involve or address environmental media, such as air, land, water or any aspects thereof; and that involve or relate to the regulation of any aspect of land or water use that may contribute to anthropogenic eutrophication; or that may provide support thereto, include: 💧 agriculture; 💧 the environment; 💧 human settlements; 💧 infrastructure; 💧 mining; and 💧 water and sanitation. These competencies are linked to responsible authorities in Chapter 5 of Part 3 that addresses ***"Governance"***, and that gives additional resolution to the assigning of roles and responsibilities in a eutrophication management context.

2.1.2 Prescribed approach

Source Directed Management involves the application of regulatory and other measures and controls, which are imposed on land and water use activities to achieve designated levels of water resource protection.

It is endeavoured to control the causes of anthropogenic eutrophication at the sources of impact[106] first, by employing operational strategies, such as best management practices; authorisations[107] and conditional regulation, including the use of emission standards[108] and pollution management regulations, made in terms of enabling legislation; and others, in accordance with the policy on the application of management instruments for environmental compliance.[109] Source Directed Management focusses mostly on regulatory approaches, but must, where appropriate, also include other management instruments that facilitate pollution avoidance, prevention, and minimisation, as required by policy.[110] Additionally,

[105] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

[106] Refer to **POLICY STATEMENT 6:** A life cycle view on nutrient-loading.

[107] Includes any environmental authorisation, including water use authorisations, such as a water use licence.

[108] Can relate to WDSs or Ambient Air Quality and Emission Standards.

[109] Refer to **POLICY STATEMENT 1:** Application of management instruments for environmental compliance in eutrophication management.

[110] Refer to **POLICY STATEMENT 2:** The Mitigation Hierarchy for decision-making on eutrophication.

incentivised regulation forms an important part of Source Directed Management and must be fully explored, developed and rolled out, as per the policy on incentive-based regulation.[111]

Source Directed Management is operationalised through several operational strategies, as elaborated in Chapter 3 of Part 3, which can be shared with any of the two other core strategies, such as water quality monitoring[90], or which can be unique to Source Directed Management, such as the regulation of land and water use. Source Directed Management is supported through the supporting strategies, as elaborated under Chapter 4 of Part 3.

Although Source Directed and Resource Directed Management are at different ends of the spectrum of eutrophication management focus, source directed measures and controls are driven by the RDMs in place, in particular RQOs and their supporting RWQOs/ WQPLs. RDMs designate levels of protection to significant water resources and are addressed under the second core strategy, dealing with Resource Directed Management (**Section 2.2**, Part 3).

2.1.3 Spatial scale of implementation

Source directed measures and controls can be categorised in terms of scales of geographical focus, as follows:

- Best management practices, and other measures or controls, which apply to land and water uses, **nationally**, or that apply to a specific land or water use type or category;
- **Catchment or regional** interventions, and other measures or controls, which are required by regional or catchment[21] management strategies and/or regional or catchment-level water quality planning; and
- **Source specific** interventions associated with any land and water use authorisation process, and other measures or controls, which apply to specific activities or sources of pollution.

Source directed measures and controls, thus, can be uniform and can apply nationally, regionally, or on a catchment basis, can discriminate according to land, water use or activity types or other forms of categorisation, or can be source specific. Importantly, source directed measures and controls, whether uniform or source specific, are always implemented by land and water use activities, in line with policy,[112] at the sources of impact to avoid, prevent or minimise water pollution[155].

2.1.4 Temporal scale of implementation

Prioritisation of not only the development and implementation, but also the revision of source directed measures and controls, will be mostly dictated by signals arising from the implementation of catchment management strategies and/or overall long-term water quality planning. Current and additional source directed measures and controls must be considered and developed, or, where necessary, refined and improved for implementation. Attention must be devoted to operationalise the Receiving Water Quality Objectives Approach.[113] The actions listed in **TABLE 14** are more of a strategic nature. Actions of a more operational nature are included under Chapter 3 of Part 3.

[111] Refer to **POLICY STATEMENT 7:** Incentive-based regulation.

[112] Refer to **POLICY STATEMENT 2:** The Mitigation Hierarchy for decision-making on eutrophication.

[113] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives Approach applied to eutrophication management.

TABLE 14: Strategic actions to strengthen the source directed management of eutrophication.

	SHORT TERM
1	Develop and implement (an) approach(es) to ensure that the conditions in water use authorisations, including those that specify WDSs, ensure compliance to statutory RDMs, specifically RQOs. Better integration between Source and Resource Directed Management is essential;
2	Evaluate and/or develop model by-laws, in support of local government, to limit excessive nutrient-loading and to protect raw water quality;
3	Develop and gazette water management regulations for impacting sectors (*e.g.*, feedlots, industries, etc.) that also contribute towards anthropogenic eutrophication;
4	The umbrella Environmental Offset Policy [DEFF, 2018] requires the DWS to compile and publish specific sector offset policies for wetlands and for water quality to enable the rolling out of offsetting for eutrophication management; and
5	In cases where regulations or compulsory national standards were made or were prescribed in terms of the NWA (36:1998) or the WSA (108:1997), an evaluation can be considered of the suitability and/or effectiveness of those measures that deal with the control and regulation of sources of anthropogenic eutrophication – specifically also their suitability to assist with realising the Eutrophication Management Goal. In cases where the enabling legislation allows for the making of regulations that could assist with the management of sources of anthropogenic eutrophication, but such regulations do not exist, consideration must be given to the development and publication of such regulations.
	LONGER TERM
6	Develop and implement a Diffuse Source Management Strategy for South Africa that harmonises with, and supports the Eutrophication Management Strategy for South Africa; and
7	Develop and implement sector specific action plans to reduce diffuse source pollution (in support of the Diffuse Source Management Strategy for South Africa).

2.2 Resource Directed Management

2.2.1 Authority

The DWS is mandated with the management of the country's water resources [NWA, 1998, S.3] and the Minister of Water and Sanitation, through the Director-General, any organ of state or any Water Management Institution[154], when exercising powers or performing duties under the NWA (36:1998), must give effect to RDMs, determined for significant water resources [NWA, 1998, S.15]. While the national government, through the DWS, is the trustee of the nation's water resources and while accepting that a strong link exists between RDMs, and source and remediation directed management of eutrophication, the role of other authorities[114] in managing aspects of land and water use must also be acknowledged.

The relevant competencies (sectors) that deals with Resource Directed Management and eutrophication, or aspects of the receiving water resource, include: ♦ disaster management; ♦ the environment; ♦ health; ♦ land use and development planning; and ♦ water and sanitation. These competencies are linked to responsible authorities in Chapter 5 of Part 3 that addresses ***"Governance"***, and that gives additional resolution to the assigning of roles and responsibilities in a eutrophication management context.

2.2.2 Prescribed approach

Resource directed management of anthropogenic eutrophication, inherently, has a catchment and water resources perspective.[115] The ultimate purpose of Resource Directed Management is to ensure continued

[114] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.
[115] Refer to **POLICY STATEMENT 10**: Holistic eutrophication management.

fitness-for-use of the country's water resources, which are being used by five groups of recognised water users; these being:

- Agriculture;
- Domestic;
- Industry;
- Recreation; and also
- Aquatic ecosystems.

In order to realise this *"ultimate purpose"* - a sound understanding[116] is essential, *inter alia,* of the nature of, and the relationships between water resources and their quality; current and future water users and their water requirements; current and expected pressures on resource quality[124]; the intrinsic social and economic dynamics; availability of allocatable water quality,[117] desired levels of water resource protection and the potential for additional ecologically sustainable development, if any, in catchments. This information is utilised for planning, for determining management objectives[118] and for establishing strategies and plans that frame the desired eutrophication management approaches for implementation over time. These management strategies and plans, amongst others, must also be utilised for the purpose of monitoring and evaluating the implementation progress.

Resource Directed Management must direct both the source and remediation directed management of eutrophication in catchments, as follows:

- RDMs must influence Source Directed Management, and any WDSs, that are applied to upstream water uses in order to protect downstream aquatic ecosystems and water users, and to ensure continued fitness-for-use of receiving water resources; and
- RDMs must influence Remediation Directed Management, such that-
  - upstream residual sources of excessive nutrient-loading, such as degraded land, are ameliorated to protect downstream aquatic ecosystems and water users, and to ensure continued fitness-for-use of receiving water resources; and
  - degraded or impaired receiving water resources and associated aquatic ecosystems are ameliorated to meet the applicable RDMs, specifically the Reserve[122], if determined, and any other environmental requirements that may exist.

It is therefore vital that all three core strategies for eutrophication management must be harmonised and that RDMs must integrate with the relevant source and remediation directed measures and controls.

Resource Directed Management is operationalised through several operational strategies, as elaborated in Chapter 3, Part 3, which can be shared between any of the other two core strategies, such as water quality monitoring, or which can be unique to Resource Directed Management, such as the determination of statutory RDMs. Resource Directed Management is supported through the supporting strategies, as elaborated under Chapter 4 of Part 3.

2.2.3 Spatial scale of implementation

Whereas the resource directed management of eutrophication has a catchment and receiving water resource focus, it is also of national interest, since it considers the fitness-for-use of water resources that support the national economy.

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116 Refer to **POLICY STATEMENT 14**: Water resource assessment and planning to inform decision-making.

117 Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives Approach applied to eutrophication management.

118 Management objectives include the Water Resource Class, RQOs, Reserves, and supporting RWQOs or WQPLs.

From a catchment and receiving water resource perspective – the resource directed management of anthropogenic eutrophication must consider all relevant attributes within a particular catchment when assessing that catchment for forward planning, goal setting and intervention planning. Additionally, to the *"inward"* catchment focus, it is also important to consider possible *"outward"* linkages that may exist between catchments. Such linkages, for example, may include inter-basin or return-flow transfers between catchments, potentially affecting the trophic status[145] in adjacent receiving catchments. Another important consideration is the fact that Water Management Areas (WMAs) and catchments are not necessarily always aligned, and that eutrophication causes and effects may sometimes be located in different management areas. In such cases, collaboration and management participation[119] are important.

Although not explicitly mentioned above, groundwater and its influences on surface water resources, and *vice versa,* must also be considered in the resource directed management of eutrophication. Good quality groundwater and interflow support base-flow, and thus, also the assimilative capacity in many freshwater[62] systems. In addition, the boundaries of hydro-geological regions and catchment areas often don't correspond, and in some cases link different catchments by providing potential underground pollution pathways. The presence of extensive opencast or underground mining may act as an aggravating factor.

Within the national dimension, national decision-makers will have to be made aware that anthropogenic eutrophication and the hypertrophic[69] conditions that exist, or that are emerging, in many of our impoundments cannot continue to be accommodated. Socio-economic development and related policy and strategy development and implementation must be aligned with the requirement of maintaining the availability and viability of the country's water resources and associated ecological infrastructure. Hence, it must be endeavoured to elevate eutrophication management and water resource protection to the same level and consideration as Government's other national priorities, such as economic growth, poverty eradication, rural development, etc. This effort will also involve demonstrating that water resource management must be integrated into the national economy, recognising the vital role of water for satisfying basic human needs, provision of food and food security, poverty alleviation and ecosystem[46] maintenance.

2.2.4 Temporal scale of implementation

The DWS has made good progress with the determination of RDMs nationally, starting with priority WMAs. Additionally, RWQOs/ WQPLs, in support of Resource Directed Management, are also becoming available in many sub-catchments. It is now vital that the Receiving Water Quality Objectives Approach[119] be operationalised[120] to improve the trophic status of many eutrophic water resources, through the application of appropriate source directed measures and controls.

A number of concrete actions in support of the resource directed management of eutrophication have been identified and are listed in **TABLE 15**. The actions listed in **TABLE 15** are more of a strategic nature. Actions of a more operational nature are included under Chapter 3 of Part 3.

[119] Refer to **Section 4.3, Part 3**: Collaboration and management participation.

[120] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives Approach applied to eutrophication management.

TABLE 15: Strategic actions to strengthen the resource directed management of eutrophication.

	SHORT TERM
1	Operationalise the Receiving Water Quality Objectives Approach and achieve compliance to the requirements of the Water Resource Class(es) (and RQOs/ Reserves) and/or supporting RWQOs/ WQPLs. Better integration between Source and Resource Directed Management is essential;
2	Gazette regulations to protect high yield water source areas, particularly the strategic water source areas (*i.e.,* strategic surface water source and critical groundwater recharge areas); and
3	In cases where regulations or compulsory national standards were made or were prescribed in terms of the NWA (36:1998) or the WSA (108:1997), evaluation can be considered of the suitability and/or effectiveness of those measures that deal with the protection of water resources against anthropogenic eutrophication – specifically also their suitability to assist with realising the Eutrophication Management Goal. In cases where the enabling legislation allows for the making of regulations that could assist with the protections of water resources against the effects of anthropogenic eutrophication, but such regulations do not exist, consideration must be given to the development and publication of such regulations.
4	Support SDG 6.3.2D and internalise reporting on the fitness-for-use of South Africa's water resources.

2.3 Remediation Directed Management

2.3.1 Authority

Remedial action, relevant to the management of eutrophication, focusses on residual pollution sources causing excessive nutrient-loading of water resources, and degraded, impaired and contaminated land areas and water resources. Remedial action is generally subject to an array of regulatory requirements and may also be based on assessments of human health and ecological risk factors where no legislated standards exist, or where standards are advisory. Remedial action can be required by other authorities,[121] in addition to the DWS.

The relevant competencies (sectors), where requirements for remediation[121] to protect water resources and aquatic ecosystems may exist, include: ♦ agriculture; ♦ the environment; ♦ mining; and ♦ water and sanitation. These competencies are linked to responsible authorities in Chapter 5 of Part 3 that addresses ***"Governance"***, and that gives additional resolution to the assigning of roles and responsibilities in a eutrophication management context.

2.3.2 Prescribed approach

Remediation directed eutrophication management relates to those measures and controls that must be adopted and enforced to effect-

- amelioration of residual sources of excessive nutrient-loading, such as land areas that are contaminated, to meet the statutory RDMs, specifically RQOs determined for receiving water resources, if available; as well as the
- amelioration of degraded or impaired receiving water resources and associated aquatic ecosystems to meet the applicable statutory RDMs, specifically the Reserve, if available, and any other environmental requirements that may exist.

To date, and in the absence of a dedicated remediation strategy to guide the removal of contaminants from, amongst others, soil, surface water, groundwater and sediment that may also exacerbate eutrophic[57] conditions in receiving water resources, regulatory instruments (not necessarily developed to

[121] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

address remediation) are being applied to manage situations requiring remediation. This resulted in inadequate and/or inconsistent handling of legacy water pollution cases. More emphasis on Remediation Directed Management should elevate regulatory capabilities to levels equivalent to those related to the source and resource directed management of eutrophication. An amendment to the NWA (36:1998) to, *inter alia*, enforce financial provisioning to address *post facto* remedial activities must be considered.[122]

Legacy stores of phosphorus (P) and nitrogen (N) in catchments may be sufficient to sustain algal blooms and hypertrophic conditions in water resources for decades to come and more innovation is needed to drawdown and recover these nutrients[97]. Agriculture's impact on eutrophication risk may be overestimated in many catchments, and more accurate accounting of sources,[123] their bio-availabilities and lag times are needed to direct proportioned mitigation efforts more effectively [Withers, et al., 2014]. All sectors of society must clearly use P and N more efficiently to develop long-term sustainable solutions to this complex issue, and nutrient reduction strategies should take account of the whole catchment-to-coast continuum. However, the right balance of local interventions (including additional biophysical controls)[124] will need to be highly site specific[125] and better informed by research[126] that unravels the linkages between sustainable practices, patterns of nutrient delivery, biological response and recovery trajectories in different types of waterbodies.

In keeping with the thrust to use water resources sustainably, to protect water resources and to ensure fitness-for-use of receiving water resources, residual pollution sources causing excessive nutrient-loading, and impaired and degraded water resources and associated aquatic ecosystems must be ameliorated or replaced at a rate that, at least, matches the rate of contamination, degradation and destruction.

As a rule, the polluter-pays-principle[127] will be applied to the cleaning-up of legacy pollution cases. Financing and implementing remediation in those cases deemed to be the State's responsibility will continue. Remediation will be implemented on a case-by-case basis, depending on the relative risk levels[128] and priorities assigned to them. In cases where remedial action is associated with existing land or water use activities, care must be taken to ensure that appropriate source directed measures and controls are in place prior to any remediation being undertaken.

2.3.3 Spatial scale of implementation

Remediation directed measures and controls for the management of eutrophication are applied locally to specific legacy sources of excessive nutrient-loading, or to specific impaired or degraded surface and/or groundwater resources and associated aquatic ecosystems. In the case of multiple sources and/or resources that require remediation, such remedial action could assume a regional or a catchment character. Therefore, remediation will not only be promoted on a facility or site level, but also at a broader operational level by actively supporting remediation research as well as incorporating it in regional planning.[129]

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[122] Refer to **Annexure H** for a list of all recommended legislative amendments.

[123] Refer to **Section 3.1.2.2.2, Part 3**: Waste load accounting.

[124] Refer to **Section 3.4.2.1.4, Part 3**: The remediation of adversely affected water resources.

[125] Refer to **Section 3.1.2.4.6, Part 3**: Establishment of geographical water quality management strategies and thematic plans.

[126] Refer to **Section 4.2, Part 3**: Research and technology development to address eutrophication-related challenges.

[127] Refer to **POLICY STATEMENT 7**: Incentive-based regulation.

[128] Refer to **Section 3.2.2.2.12, Part 3**: Differentiated water use management based on risk.

[129] Refer to **Section 3.1, Part 3:** The *"plan"* stage.

2.3.4 Temporal scale of implementation

In the absence of remediation strategies to guide the remediation directed management of eutrophication, available regulatory instruments to handle situations requiring remediation will be applied. **TABLE 16** provides a list of actions necessary to provide momentum to the roll-out of the remediation directed management of eutrophication. The actions listed in **TABLE 16** are more of a strategic nature. Actions of a more operational nature are included under Chapter 3 of Part 3.

TABLE 16: Strategic actions to strengthen the remediation directed management of eutrophication.

	SHORT-TERM
1	Establish a *"Remediation Working Group"* to initiate the development of the necessary instruments and to guide remedial activities;
2	Develop and implement a dedicated Remediation Strategy for South Africa to guide the removal of contaminants from, amongst others, soil, surface water, groundwater and sediment, which may also exacerbate eutrophic conditions in receiving water resources;
3	Investigate the implementation of financial provision, in conjunction with the WDCS, to cover the cost of remedial action;
4	Develop a risk-based approach to prioritise remedial action;
5	Investigate and develop desired remediation *"clean-up levels"* or *"targets"* that support the statutory RDMs. All eutrophication concerns must be suitably addressed by any remedial action to be taken;
6	Develop rule-based best management practice measures to inform remedial action; and
7	In cases where regulations or compulsory national standards were made or were prescribed in terms of the NWA (36:1998) or the WSA (108:1997), it can be considered to evaluate the suitability and/or effectiveness of those measures that potentially deal with any remedial actions that relate to anthropogenic eutrophication – specifically also their suitability to assist with realising the Eutrophication Management Goal. In cases where the enabling legislation allows for the making of regulations that could potentially assist with the management of anthropogenic eutrophication through remedial action, but such regulations do not exist, consideration must be given to the development and publication of such regulations.
	LONGER TERM
8	Develop and implement a programme to remediate priority impoundments and water resources, such as the Hartbeespoort Dam, in accordance with relevant geographical water quality management strategies and thematic plans, utilising revenue from the WDCS. Cognisance must be taken of lessons learned through the Harties-Metsi-A-Me project.

CHAPTER 3: OPERATIONAL STRATEGIES

The *operational eutrophication management strategies* have a dual purpose, namely to–

- **complement the core strategies for eutrophication management**, by providing additional resolution on the four stages within the water quality management framework, specifically in relation to eutrophication; and
- **provide further operational guidance to eutrophication management** in South Africa.

Since the operational strategies for eutrophication management cannot necessarily be arranged individually in a tiered and hierarchical fashion under the three core strategies for eutrophication management, and since many of these operational strategies are common to more than one core strategy, the operational strategies for eutrophication management have been structured within an accepted international framework for management systems, known as the Shewhart-Deming or PDCA Cycle [Moen & Norman, 2009]. PDCA stands for *"**P**lan-**D**o-**C**heck-**A**ct"*, and represents a generic management framework, with *"learning-by-doing"*, or continuous management improvement, as a key characteristic.[130]

FIGURE 40 provides a conceptual framework for the operational management of eutrophication in South Africa.[131] A limited number of case studies, in support of some of the operational strategies for eutrophication management, were included, within insert boxes in Chapter 3 of Part 3.

3.1 The *"plan"* stage

Altogether the *"plan"* stage, in the eutrophication management framework, must–

- consult and learn from stakeholders, and establish common ground and buy-in;
- gather a suitable base of catchment information that will support the management of eutrophication;
- limit uncertainties and generate essential eutrophication management intelligence to promote high confidence and informed decision-making;
- proactively identify stumbling blocks, maximise strengths and utilise opportunities;
- make informed predictions of what can be expected in future, in order to be prepared for the potential management outcomes;
- identify desired and clear endpoints, and enlightens what need to be done to realise the desired effects;
- produce coherent strategies and/or plans that consider the relevant catchment dynamics;
- coordinate efforts, if necessary, across sectors, and avoid *ad-hoc* actions and responses where managers must attend to successive crises in the absence of clear and holistic eutrophication plans or goals;
- promote responsibility and accountability;
- structure the allocation of scarce resources – *i.e.,* financial and human capital, time, information, equipment, etc. – to implement strategies and plans, and to achieve goals; and
- assess and evaluate the implementation progress according to a pre-determined planned procedure, regularly and effectively to support the adaptive management process.

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[130] The PDCA Cycle is handy for describing the nature of water quality management [Van Wyk, et al., 2003]. For easy reference purposes, all the operational strategies for the management of eutrophication are also presented within the context of the PDCA Cycle.

[131] Though it is acknowledged that the operational strategies, within this framework for the management of eutrophication, can individually also be considered in a ***P**lan-**D**o-**C**heck-**A**ct"* fashion, *i.e. "Domestic status and trends monitoring and reporting"*, for instance, is also *"planned"*, *"rolled out"*, *"verified"* for efficacy and *"improved"*, if necessary, the focus in Chapter 3, of this part of the document, is on the **MANAGEMENT OF EUTROPHICATION** and not the management of the individual operational strategies.

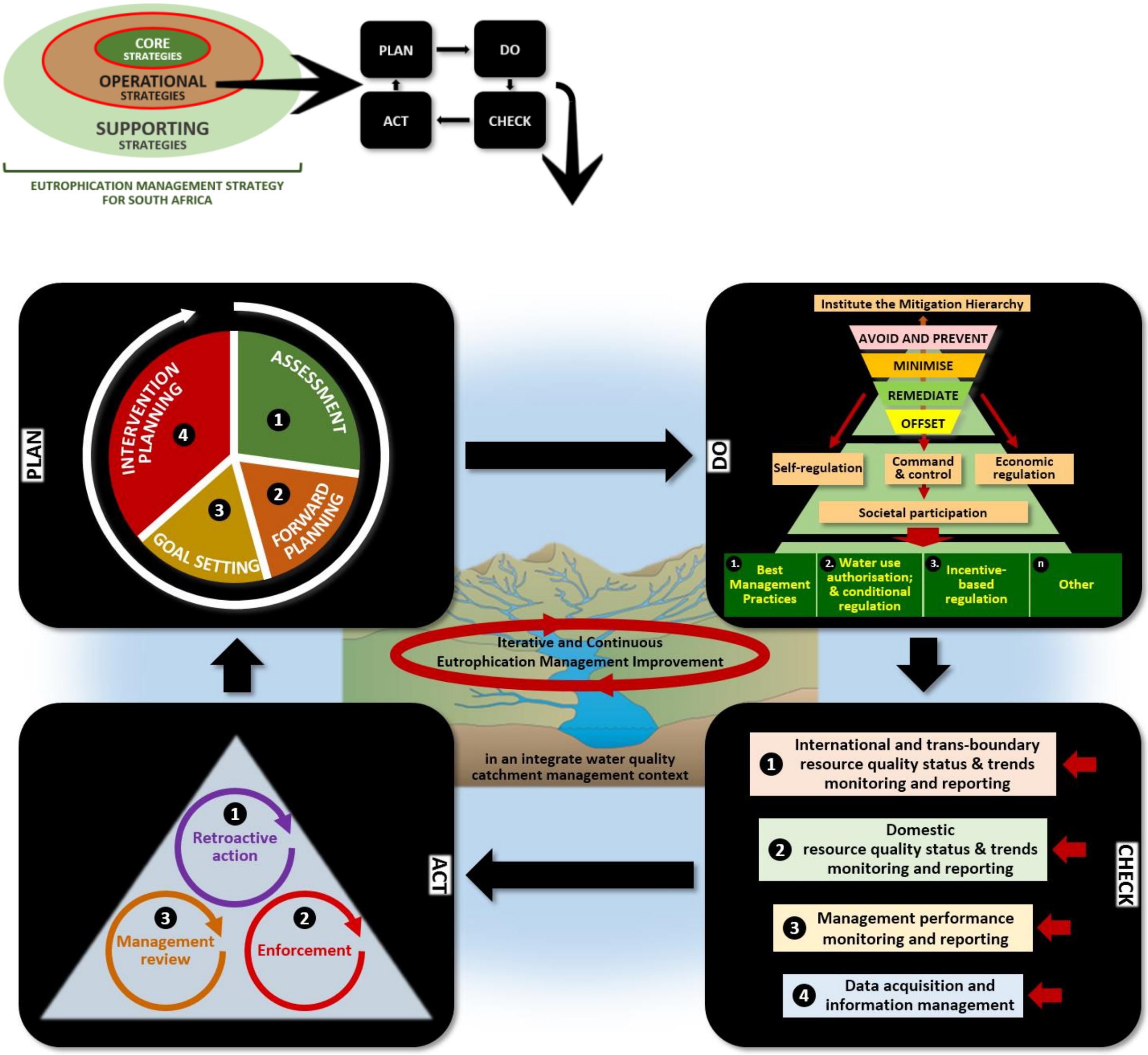

FIGURE 40: Framework with operational strategies for the management of eutrophication.

Planning to address eutrophication in South Africa is essential and is executed within an accepted framework for water quality planning. A simplified schematic of this framework is depicted in **FIGURE 41** in the form of a planning cycle, showing the four operational strategies, dealing with (1) *"Assessment"*; (2) *"Forward planning"*; (3) *"Goal* setting*"*; and (4) *"Intervention planning"*. Although the chronology of individual operational strategies and their components in the Cycle is illustrated, the linkages that exist between these operational strategies and their components, are not. Iterative linkages exist between the individual components and are elaborated in **Section 3.1.2**, Part 3 below. Connections between the individual components are indicated through the inclusion of footnotes with cross-reference to such other components.

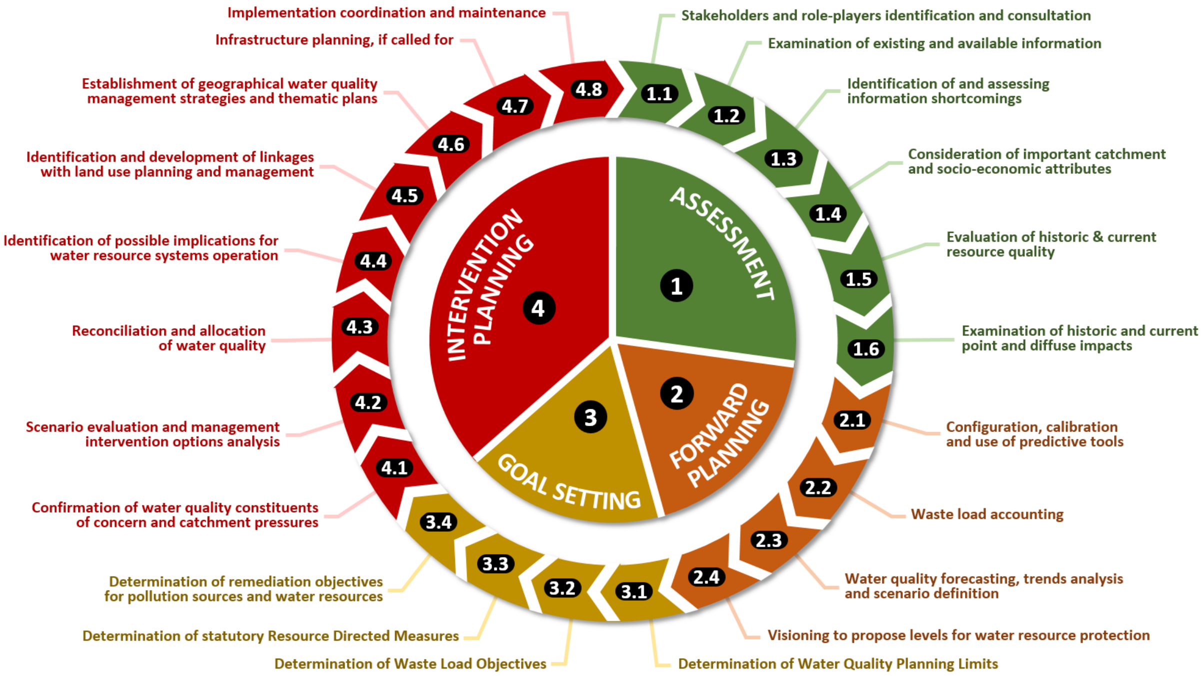

FIGURE 41: Planning for eutrophication management.

The *"plan"* stage, in the eutrophication management framework, comprises four linked operational strategies [adapted from DWAF, 2003a]. These operational strategies, and their purpose and composition, are summarised in **TABLE 17.**

TABLE 17: The operational strategies in the "plan" stage of the eutrophication management framework, and their composition.

OPERATIONAL STRATEGIES AND PURPOSE		KEY COMPONENT(S)
1. Assessment	*To describe and understand the catchment, or geographical area, and the water resources, under investigation.*	Stakeholders and role-player identification and consultation;
		Examination of existing and available information;
		Identification of and assessing information shortcomings;
		Consideration of important catchment and socio-economic attributes;
		Evaluation of the historic and current resource quality; and
		Examination of historic and current point and diffuse impacts.
2. Forward planning	*To support decision-making by adding value to the assessment.*	Configuration, calibration and use of predictive tools;
		Waste load accounting;
		Water quality forecasting, trends analysis and scenario definition; and
		Visioning to propose levels for water resource protection.
3. Goal setting	*To define desired outcomes, based on information from the assessment and forward planning.*	Determination of Resource Water Quality Objectives or Water Quality Planning Limits;
		Determination of Waste Load Objectives;
		Determination of statutory Resource Directed Measures; and
		Determination of remediation objectives for pollution sources and water resources.

OPERATIONAL STRATEGIES AND PURPOSE		KEY COMPONENT(S)
4. Intervention planning	*To devise detailed approaches to realise the desired outcomes.*	Confirmation of the water quality constituents of concern and catchment pressures;
		Scenario evaluation and management intervention options analysis;
		Reconciliation and allocation of water quality;
		Identification of possible implications for water resource systems operation;
		Identification and development of linkages with land use planning and management;
		Establishment of geographical water quality management strategies and thematic plans;
		Infrastructure planning, if called for; and
		Implementation coordination and maintenance.

3.1.1 Authority

There are a number of role-player authorities, in addition to the DWS, who play roles during the *"plan"* stage of eutrophication management,[132] and whose actions may, to a greater or to a lesser extent, influence or affect the trophic status of receiving water resources. Especially authorities outside the water sector who deal with the management of land uses and development planning and who should be cognisant of the implications of their actions for eutrophication. Competencies (sectors), which are relevant here, include: the environment; health; land use and development planning; and water and sanitation. These competencies are linked to responsible authorities in Chapter 5 of Part 3 that addresses ***"Governance"***, and that gives additional resolution to the assigning of roles and responsibilities in a eutrophication management context.

3.1.2 Prescribed approaches

3.1.2.1 Assessment

"If you can't explain it simply, you don't understand it well enough!" Author: Albert Einstein

The complexities and uncertainties associated with land use and water resource management, specifically the management of eutrophication, and the need for a sound understanding of processes and issues, require thorough appraisal and development of knowledge systems that must serve as a basis for informing water resource goal setting, planning, management and remediation.

A catchment assessment study[133] is the process of collating, processing and interpreting data and information about water-related conditions, issues and developments within a catchment context. The catchment assessment must provide a statement on the historic and present status of the catchment in question, and as such, includes data and information that are required for informed eutrophication planning and management. The nature of the catchment assessment study [adapted from DWAF, 2003a] is discussed next:

[132] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

[133] Refer to **POLICY STATEMENT 14**: Water resource assessment and planning to inform decision-making.

3.1.2.1.1 Stakeholders and role-player identification and consultation

An identification of catchment stakeholders and role-players, relevant institutional arrangements and linkages to assist with consultative processes,[134] information gathering and management participation,[135] must be undertaken.

Knowledge about interested individuals and institutions, who have a stake in eutrophication management issues, for whatever reason, will ensure that such parties are recognised and given an opportunity to make inputs. Local and available expert knowledge on eutrophication should be utilised to complement and augment existing sources of available information, knowledge and expertise, as may be necessary.[136]

Furthermore, the trophic status of receiving water resources is closely linked to land use and other physical developments that may cause excessive nutrient-loading during the terrestrial phase of the hydrological cycle. Control over many of these land uses and physical developments, however, lies outside the statutory domain of the NWA (36:1998), and other laws and authorities, other than the DWS or Water Management Institutions, have jurisdiction over many of these activities that might contribute to anthropogenic eutrophication. Against this fragmented background, and in the interest of management cooperation, it is imperative that the relevant institutional arrangements and linkages must be understood and suitably mobilised in support of the eutrophication management goal, objectives and policy imperatives.

3.1.2.1.2 Examination of existing and available information

Some experienced-based understanding of the functioning of at least some parts of a catchment is usually present among some longstanding catchment inhabitants, as well as among government officials or professionals active in water-related matters within that catchment.[137] Similarly, the existence of water-related issues and problems is often common knowledge and/or particular water-related studies have historically been conducted in the catchment(s) under consideration.[138] Relevant sources of existing information must be identified, acquired and considered to prevent undue duplication of effort and to utilise scarce government resources effectively.

3.1.2.1.3 Identification of and assessing information shortcomings

Additional field surveys and investigations, if necessary, must be considered as a means of addressing eutrophication-related information shortcomings. This includes undertaking additional *"snapshot"* sampling drives[139] to support catchment assessment. The utilisation of technology tools, such as remote sensing to assess the effects of eutrophication [Matthews & Bernard, 2015], can be considered during the evaluation of the historic and current resource quality[140] to augment eutrophication monitoring data and information availability. Additionally, modelling and data gap infilling to produce extrapolated data and information, albeit not at the same confidence level as actual data, can be considered during the calibration and use of predictive tools.[141]

Sufficient and appropriate data are indispensable to meaningful forward planning, goal setting and intervention planning. Insufficient data and information reduce confidence in planning recommendations

[134] Refer to **POLICY STATEMENT 17**: Transparency.

[135] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

[136] Refer to **POLICY STATEMENT 4**: The application of the Precautionary Principle.

[137] Refer to **Section 3.1.2.1.1, Part 3**: Stakeholders and role-player identification and consultation.

[138] Refer to **Section 3.1.2.4.1, Part 3**: Confirmation of the water quality constituents of concern and catchment pressures.

[139] Refers to once-off sampling run(s), *e.g.,* once under low-flow and once under high-flow conditions to augment currently available data and information.

[140] Refer to **Section 3.1.2.1.5, Part 3**: Evaluation of the historic and current resource quality.

[141] Refer to **Section 3.1.2.2.1, Part 3**: Configuration, calibration and use of predictive tools.

and appropriate monitoring, analysis and data handling[142] is indispensable to the effective management of eutrophication.

3.1.2.1.4 Consideration of important catchment and socio-economic attributes

Consideration must be given to all relevant natural and anthropogenic attributes, their linkages and the concomitant socio-economic characteristics in the catchment in question. These may relate to any of the following; noting that the categories are not necessarily mutually exclusive or representing exhaustive inventories of attributes:

- **WATER RESOURCE SYSTEM ATTRIBUTES:**
  - **River system details –** such as main stem and tributary channel locations, names and characteristics; spatial catchment and sub-catchment information, including the primary, secondary, tertiary, quaternary and/or quinary drainage region[118] boundaries, as may be necessary; and spatial estuary details, if relevant.
  - **Groundwater details –** such as aquifer locations, boundaries and characteristics.
  - **Water use information –** water uses with a potential to exacerbate the trophic status of receiving water resources must be identified, *inter alia*, by utilising data and information stored in WARMS, or by undertaking Validation and Verification (V&V) studies for waste and water containing waste related water uses.[143]
  - **Water infrastructure information –** such as locations, names and sizes of storage dams; balancing reservoirs; irrigation schemes; water transfer schemes; and water and WwTWs.
  - **Resource quality monitoring information –** such as details on surface and groundwater, effluent[48], and flow gauging stations;[144] and water quality, river health and flow data.
  - **Weather monitoring and climate information –** such as details on rainfall, weather and evaporation stations; and rainfall, runoff and evaporation data.
  - **Existing resource objectives –** if any, notably the Water Resource Class(es) (and RQOs/ Reserves) and/or supporting RWQOs/ WQPLs and/or remediation objectives, must be identified for further consideration during goal setting.[145]
  - **Water management strategies and plans –** such as the National Water Resource Strategy (NWRS), National Water and Sanitation Master Plan (NW&S MP), Catchment Management Strategies (CMSs) and Water Services Development Plans (WSDPs) must be sourced for further consideration during geographical water quality management strategies and thematic plans establishment.[146]
  - **Transboundary requirements or obligations –** if any, relevant to eutrophication management must be identified and examined.
- **BIO-PHYSICAL ATTRIBUTES:**
  - **Natural features –** such as geology; soil types; topography; vegetation; wetlands; erosion and sediment production potential.
  - **Areas and ecological infrastructure that must be protected –** such as nature reserves; indigenous veld and forests; National Freshwater Ecosystem Priority Areas (NFEPAs); high yield water source areas, particularly the strategic water source areas;[147] Ramsar Wetlands; buffer areas; and others.[148]

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[142] Refer to **Section 3.3.2.4, Part 3**: Data acquisition and information management.
[143] Refer to **Section 3.1.2.1.6, Part 3**: Examination of historic and current point and diffuse impacts.
[144] Refer to **Section 3.1.2.1.5, Part 3**: Evaluation of the historic and current resource quality.
[145] Refer to **Section 3.1.2.3, Part 3**: Goal setting.
[146] Refer to **Section 3.1.2.4.6, Part 3**: Establishment of geographical water quality management strategies and thematic plans.
[147] Refer to **Section 3.1.2.2.4, Part 3**: Visioning to propose levels for water resource protection.
[148] Refer to **POLICY STATEMENT 8**: Nature-based solutions.

- **DEMOGRAPHIC ATTRIBUTES:**
  - **Population statistics –** such as the size, structure, and temporal and spatial changes in population numbers that are necessary to analyse and predict socio-economic trends, and water demand and water quality impact trends.
- **SOCIO-POLITICAL AND DEVELOPMENTAL ATTRIBUTES:**
  - **Socio-economic profiles –** such as the types and extent of economic outputs per management unit[82] in terms of absolute values, as well as proportion of Gross Domestic Product (GDP), Gross National Product (GNP) and per capita. An understanding, specifically of the social and economic dynamics at play, is used in the analysis of options, such as through Cost-Benefit Analyses being applied in scenario evaluation.[149]
  - **Areas, jurisdictions and boundaries –** such as WMAs, CMAs and other Water Management Institutions; municipal areas and Water Services Institutions[159], etc. and also others relating to the municipal, provincial, national and transboundary scales.[150]
  - **Other infrastructure details –** such as the location of major roads and railway lines.
- **LAND USE ATTRIBUTES:**
  - **Land use information –** such as different categories of human settlements, commercial and industrial areas, different categories of irrigation activities, commercial and other plantations, dryland agriculture, mining activities, and waste disposal sites.[151]
  - **Other strategies, plans or the like –** that may have relevance, or that may affect eutrophication management in the catchment in question, such as provincial growth strategies, Integrated Development Plans (IDPs), Environmental Management Frameworks (EMFs), etc. must be sourced for further consideration during the identification and development of linkages with land use management.[152]

3.1.2.1.5 Evaluation of the historic and current resource quality

An evaluation of the historic and *status quo* resource qualities, *i.e.,* water quality, quantity and the integrity of aquatic ecosystems, is necessary to support informed eutrophication management decision-making, in specific catchments. Suitable resource quality data and information must be obtained from credible sources[153] and analysed to describe-

- the aquatic ecosystem health, water quality and flow, in the catchment, at an overview level;
- any residual effects on water resources and associated aquatic ecosystems, which have resulted from historic nutrient-loading;
- any prominent spatial trends that can be observed; and
- any temporal trends of concern.

Prior to goal setting,[154] the South African Water Quality Guidelines can be utilised as benchmark when evaluating historic and current water quality data and information. This information can be utilised to develop a preliminary understanding of the problem constituents and fitness-for-use of water resources by the individual water user groups.

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149 Refer to **Section 3.1.2.4.2, Part 3**: Scenario evaluation and management intervention options analysis.

150 Refer to **Section 3.1.2.1.1, Part 3**: Stakeholders and role-player identification and consultation.

151 Refer to **Section 3.1.2.1.6, Part 3**: Examination of historic and current point and diffuse impacts.

152 Refer to **Section 3.1.2.4.4, Part 3**: Identification and development of linkages with land use planning and management.

153 The Water Management System (WMS), maintained by Resource Quality Information Services (RQIS) of the Department of Water and Sanitation (DWS) constitutes an important source of water quality data and information.

154 Refer to **Section 3.1.2.3, Part 3**: Goal setting.

3.1.2.1.6 Examination of historic and current point and diffuse impacts

Unlike diffuse[38] sources of excessive nutrient-loading, point[112] sources of nutrient pollution are, in principle, relatively easily quantifiable. Discharge authorisation conditions usually require regular effluent sampling and flow rate monitoring. Unfortunately, unlicensed discharging, or periodic dumping of effluents by authorised dischargers in excess of prescribed conditions, does occur. Point source assessment, therefore, does not only comprise the processing of available effluent stream records, but may also include scrutiny of streamflow water quality records[155] to identify unknown contaminant loadings, which may signify unauthorised and unlawful discharges. In many instances, it may even be required to initiate the necessary V&V studies to identify and confirm all waste and water containing waste related water uses within the catchment(s) in question.

Diffuse sources of nutrient-loading represent land use types, areas and activities that result in the mobilisation and discharge of such contaminants in any manner other than through a discrete or discernible conveyance. Diffuse source nutrient-loading of surface waters in South Africa is largely caused by rainfall and the associated surface runoff[131] or groundwater discharge. Diffuse nutrient sources may be intermittent, contributing to contamination of water resources over a widespread area, such as storm wash-off and drainage from urban or agricultural areas. Alternatively, they may be concentrated, associated with localized high activity areas, such as mines, feedlots, landfills and industrial sites. Although diffuse source impacts of surface wash-off are relatively immediate, the diffuse source impact of groundwater discharge is often delayed, due to the time taken for contaminants to mobilise and move through the soil matrix into receiving surface water resources.

Whereas the identification and quantification of diffuse nutrient pollution sources may also include the scrutiny of streamflow water quality records[156] to identify unknown contaminant loadings, which may signify the presence of diffuse nutrient impacts, diffuse sources quantification mostly occurs via the calibration and use of predictive tools[157] and confirmation through waste load accounting.[158]

The following point and diffuse source information must be collected or generated:

- A summary table containing general point and diffuse impact information, such as locations, names and types, primary activities involved, identity, position and contact details of accountable persons, etc.;
- A database of annual and/or monthly historical time series of waste and water containing waste related disposal or discharge volumes and nutrient-related constituent concentrations;
- A database of raw information on waste and water containing waste related disposal or discharge volumes and sample analyses;
- A database of annual and/or monthly historical time series of diffuse waste loads, associated with waste and water containing waste related water uses. The quantification of the diffuse nutrient impacts can be derived through the calibration and use of predictive tools[159] and waste load accounting;[160] and
- A database of legacy point and diffuse nutrient sources.

[155] Refer to **Section 3.1.2.1.5, Part 3**: Evaluation of the historic and current resource quality.
[156] Refer to **Section 3.1.2.1.5, Part 3**: Evaluation of the historic and current resource quality.
[157] Refer to **Section 3.1.2.2.1, Part 3**: Configuration, calibration and use of predictive tools.
[158] Refer to **Section 3.1.2.2.2, Part 3**: Waste load accounting.
[159] Refer to **Section 3.1.2.2.1, Part 3**: Configuration, calibration and use of predictive tools.
[160] Refer to **Section 3.1.2.2.2, Part 3**: Waste load accounting.

3.1.2.2 Forward planning

"Planning is bringing the future into the present so that you can do something about it now" Author: Alan Lakein

Forward planning[161] utilises the data and information that were produced during the assessment to identify possible permutations of alternative future realities and to evaluate likely outcomes. Forward planning must provide statements on the expected and recommended future statuses of the catchment in question, and as such includes the following [adapted from DWAF, 2003a]:

3.1.2.2.1 Configuration, calibration and use of predictive tools

The configuration and calibration of water quality predictive tools require land and water use information as essential inputs.[162] Not only contemporary information, but also historical land and water use trends, with reasonably reliable records of both point and diffuse nutrient sources and their constituent loadings, are required for proper calibration of such predictive tools over a representatively long time period and with a pre-determined margin of acceptable error. Application of predictive tools plays a significant role in water quality focused forward planning, as typified below:

- The effect of **point sources** of nutrient-loading on receiving water resources, including to estimate the mixing zone, can be modelled. This will assist to determine the allocatable water quality and suitable WDSs;
- Once the contributions of point sources of nutrient-loading on streamflow and groundwater are quantified, the remaining causes of excessive nutrient-loading evident from the applicable monitoring data, must be of a diffuse nature.[163] For their quantification, contributions by diffuse nutrient sources must be estimated, as, by their very nature, diffuse nutrient source contributions cannot be measured directly. In effect, therefore, a significant component of modelling support required during eutrophication-focused forward planning, relates to **diffuse source impacts**;
- Sound management decisions may rely on the ability to **predict the outcomes of streamflow and water quality** along different river reaches and for different **scenarios**[164] of land and water use in the catchment. Various predictive approaches are available to address eutrophication-focused management questions, ranging from process-based catchment models, through to rule-based methods, to simple regression-based formulas;
- Similarly, models are also available for the **prediction of the outcomes of different ways of operating** an existing or planned river-reservoir system over an extended period;[165]
- The high variability of rainfall and streamflow from year to year in South Africa dictates that, for sound management decisions, surface water availability and water quality patterns should be assessed via long-term characteristics, so that the inherent variability is adequately recognised. Unfortunately, the reality of water quality databases is that they are limited in duration and spatial representativeness, and often comprise only intermittent samples. Mathematical predictive tools provide a way around this dilemma. Catchment modelling, driven by long sequences of rainfall, provides a useful approach to **extend or infill streamflow and surface water quality time series** synthetically,[166] with the intention of capturing temporal and spatial variability better than the data do. Alternatively, simple empirical predictive tools, driven by the statistics of long sequences of streamflow, or based on heuristic

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[161] Refer to **POLICY STATEMENT 14**: Water resource assessment and planning to inform decision-making.
[162] Refer to **Section 3.1.2.1.4, Part 3**: Consideration of important catchment and socio-economic attributes.
[163] Refer to **Section 3.1.2.2.2, Part 3**: Waste load accounting.
[164] Refer to **Section 3.1.2.2.3, Part 3**: Water quality forecasting, trends analysis and scenario definition.
[165] Refer to **Section 3.1.2.4.5, Part 3**: Identification of possible implications for water resource systems operation.
[166] Refer to **Section 3.1.2.1.3, Part 3**: Identification of and assessing information shortcomings.

interpretations of land uses, may be used for estimation of long-term statistics of particular eutrophication-related constituents of concern;[167] and

- RWQOs/ WQPLs and RDMs represent an economic balance between water user and ecological water quality requirements on the one hand, and the costs of mitigation measures to achieve the RWQOs/ WQPLs and RDMs on the other. Future scenarios[168] are typically **compared on a cost-benefit basis** by utilising predictive tools to compare the economic dis-benefit due to the water quality received by water users and the cost of a particular management option.

3.1.2.2.2 Waste load accounting

Nutrient load accounting must be utilised to balance input and output constituent specific loads, and to develop nutrient load budgets, for the sub-catchments and catchment(s) in question.

Point source nutrient loads and diffuse sources of nutrients that are collected and discharged as nutrient loads through a discrete or discernible conveyance, such as in the case of many irrigation and urban stormwater return-flows, are relatively easily quantifiable. The remaining portion of diffuse nutrient contributions cannot be measured directly, and the application of predictive tools[169] are often required. The effects of any legacy point and diffuse sources of nutrient pollution must be included in the nutrient load budgets of catchments.

The resulting nutrient load accounts set up for the sub-catchments and catchment(s) in question, will serve as basis for the reconciliation and allocation of water quality,[170] once the necessary in-water resource water quality objectives[72], and associated Nutrient Load Objectives (NLO)[171] have been determined.

3.1.2.2.3 Water quality forecasting, trends analysis and scenario definition

Water quality forecasting and trend analysis must be undertaken to predict expected future eutrophication-related pressures on resource quality. Spatial and temporal nutrient constituent concentration and nutrient load distributions must be interrogated to proactively identify areas of concern. Care must be taken to utilise time series data over a suitable period, preferably longer than five years, especially if significant seasonality is present. Seasonality occurs when one part of the year tends to produce consistently higher or lower values than other parts of the year. Water quality foresight is to be supported through nutrient modelling [172] and the evaluation of eutrophication management and developmental scenarios.

Scenarios definition and construction must yield a list of all possible eutrophication management and developmental scenarios. A preliminary screening must be undertaken to eliminate non-feasible scenarios with fatal flaws. Scenarios definition includes considering reuse and recycling of nutrient rich waste and water containing waste return-flow options, as a means to address eutrophication concerns. The identified scenarios can only be evaluated subsequent to goal setting, since scenario evaluation and management options analysis[173] are closely related and are dependent on the management objectives that are derived through goal setting.[174]

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[167] Refer to **Section 3.1.2.1.5, Part 3**: Evaluation of the historic and current resource quality.
[168] Refer to **Section 3.1.2.4.2, Part 3**: Scenario evaluation and management intervention options analysis.
[169] Refer to **Section 3.1.2.2.1, Part 3**: Configuration, calibration and use of predictive tools.
[170] Refer to **Section 3.1.2.4.3, Part 3**: Reconciliation and allocation of water quality.
[171] Refer to **Section 3.1.2.3, Part 3**: Goal setting.
[172] Refer to **Section 3.1.2.2.1, Part 3**: Configuration, calibration and use of predictive tools.
[173] Refer to **Section 3.1.2.4.2, Part 3**: Scenario evaluation and management intervention options analysis.
[174] Refer to **Section 3.1.2.3, Part 3**: Goal setting.

3.1.2.2.4 Visioning to propose levels for water resource protection

Visioning, by its nature, is both forward looking and aspirational, and provides the bridge between forward planning and goal setting. In the absence of water resource classification, visioning is necessary to fix the desired levels of water resource protection, which informs the determination of RWQOs or WQPLs,[175] and RQOs. The vision, additionally, proposes the direction of change from the *status quo* that is necessary, or that can be allowed, if justified. During the classification of water resources, visioning is inherently part of the classification process.[176]

Water use needs, water user requirements and the quality of water resources are dynamic over space and time. Visioning provides the mechanism within which this dynamic variability can be aligned towards an agreed sustainable future in a catchment context (**FIGURE 42**) [DWAF, 2006c].

The catchment vision both considers the current trophic status of water resources, and the potential for improved trophic conditions. This might result in an idealistic vision of the desired trophic status, which would have to be balanced with the concomitant impacts of land use activities on anthropogenic eutrophication. Almost all water use activities generate either point or diffuse source pollution – *i.e.* one may not insist on ideal water quality, when one's own activity contributes to the deterioration in water quality. This, therefore, leads to both the acceptance of the need to use the water resource to dispose of waste or to discharge water containing waste (including its diffuse source forms), and to the formulation of more realistic water quality requirements.

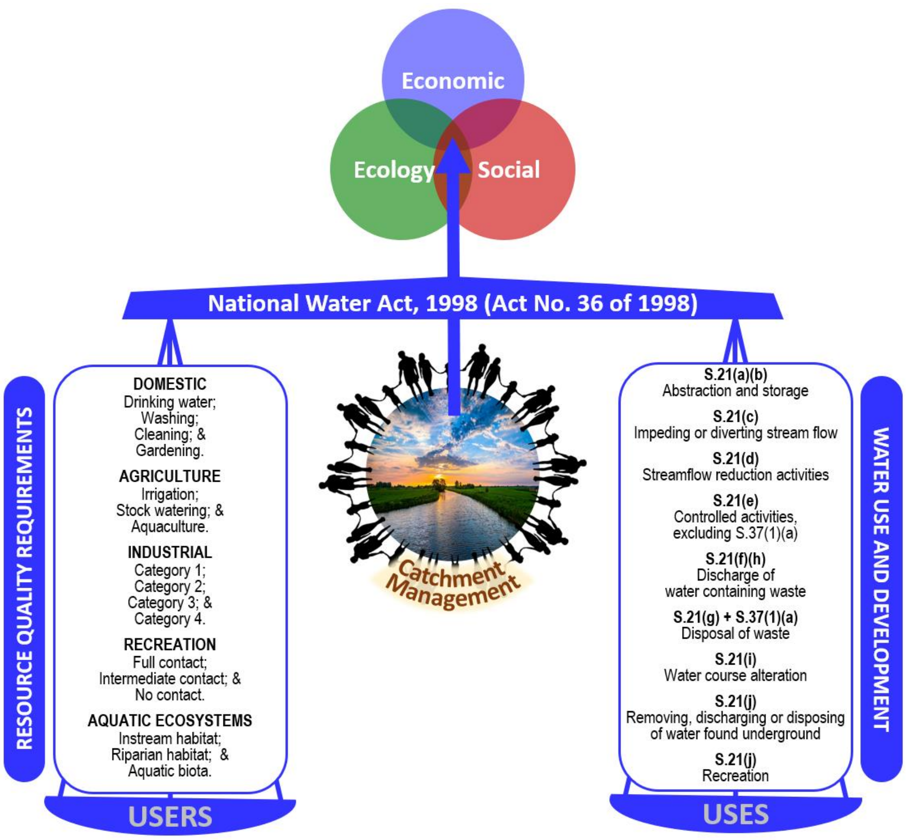

FIGURE 42: Balancing water resource protection with water resource use and development [Van Wyk, et al., 2003].

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175 The narrative descriptions commonly used to express judgements about the fitness of water resources for use are: *"ideal"*; *"acceptable"*; *"tolerable"*; and *"unacceptable"*. Visioning must relate the need to protect water resources to any of the first three levels, *i.e.* *"ideal"*; *"acceptable"*; or *"tolerable"*. *"Unacceptable"* water quality does not support ecologically sustainable development and is not an option.

176 Refer to **Section 3.1.2.3.3, Part 3**: Determination of statutory Resource Directed Measures.

3.1.2.3 Goal setting

"There is no achievement without goals." Author: Robert J. McKain

Goals are inherent building blocks of any management process. This statement is equally valid for the management of eutrophication. The goals in the eutrophication management framework direct the eutrophication management actions and efforts (during the *"Do"* stage), and also serve as a benchmark for the measuring of implementation progress and success (during the *"check"* stage), and the potential prompting of corrective steps (during the *"act"* stage), should goals not be met.

These goals, generally, comprise:

- RWQOs[127] or WQPLs[157];
- Waste load objectives[150];
- Gazetted RDMs, *i.e.,* Water Resource Class(es) (and RQOs/ Reserves);
- Remediation objectives; and
- Any other supporting management goals.

There is no ideal sequence for setting-up these goals and any of these goals can be determined first. The gazetted goals, *i.e.,* the Water Resource Class(es) (and RQOs/ Reserves), determined in terms of the Water Resource Classification System, set the tone and the other goals must support any of the said gazetted goals. In cases where statutory RDMs have not yet been determined and gazetted, but some, or all of the other goals have, such other goals will serve as input to the determination of statutory RDMs when commissioned. **Collectively, when referring to the water quality components of RQOs and to either the RWQOs or WQPLs, reference is sometimes made to *"in-water resource water quality objective"*, or *"in-stream water quality objective"* for surface water and *"in-aquifer water quality objectives"* for groundwater.**

3.1.2.3.1 Determination of Resource Water Quality Objectives or Water Quality Planning Limits

The CMA, or in the absence of the CMA, the proto-CMA, may determine *"Resource Water Quality Objectives*" (RWQOs)[127], and the DWS *"Water Quality Planning Limits"* (WQPLs)[157]. The RWQOs and WQPLs are similar in nature. Both are narrative or quantitative objectives that are determined – either in-stream or in-aquifer – within discrete management units. The management units are sub-catchment areas that are delineated considering relevant catchment and socio-economic attributes.[177] These objectives may be set at a greater spatial resolution (*i.e.,* closer together) and/or temporal resolution (*i.e.,* more frequently monitored) than the RQOs (preliminary or otherwise), to which they must be linked, if such RQOs are available and gazetted.

Catchment eutrophication management is a highly complex task. The trophic status, water quantity and aquatic ecosystem components of water resources are all interdependent and linked by a complex set of biological, physical and chemical relationships. Water quality changes continuously as water that contains waste is added to surface water resources, which is then further modified as such water flows downstream to meet estuaries, which, in turn, are also influenced by ocean tides. The trophic status of surface water resources may also be affected by abstractions, which decrease the capacity of the water resource, both the river and its estuary, to assimilate nutrients. Water in rivers may be impounded, which then realises a whole new set of biological, physical and chemical interactions, while groundwater, or water in tidal estuaries, may be subjected to an altogether different set of biological, physical and chemical interactions.

The formulation of viable in-water resource water quality objectives is perhaps one of the most important steps in the eutrophication management framework. RWQOs and WQPLs, that have the support of the

[177] Refer to **Section 3.1.2.1.4, Part 3**: Consideration of important catchment and socio-economic attributes.

stakeholders, will secure their participation in the ongoing eutrophication management process. It also sets the goals that drive the technical process of formulating Nutrient Load Objectives, the allocation of water quality,[178] and geographical strategy and thematic plan establishment.[179] It is therefore critical to ensure that this process produces feasible in-stream and in-aquafer objectives that stakeholders can support.

The formulation of the RWQOs or WQPLs should be supported by an assessment of the major point and diffuse sources of pollution, as well as of the water users in the catchment.[180] Some degree of iteration, between these assessments and the formulation of the RWQOs/ WQPLs, is likely.

Initially, assessments of water quality status would be benchmarked against the South African Water Quality Guidelines,[181] but the final water quality assessment must be based on the RWQOs/ WQPLs once these have been determined.[182] Similarly, initial assessments of the sources of pollution would be broad-brush assessments of all potential sources, but once the RWQOs/ WQPLs have been established, final pollution source assessments would be based on these in-stream and in-aquafer objectives.[183] The catchment assessment should, therefore, run in parallel with the process of formulating the RWQOs/ WQPLs.

In the case of surface water resources, RWQOs and WQPLs affect both the upstream water uses and the downstream water users (**FIGURE 43**). In determining these objectives, the DWS or CMA strives to achieve a balance between protecting the water resource for the downstream users and allowing use and development of the water resource upstream of that objective point. For the downstream water users, the focus is on protecting the water quality to ensure a healthy functional aquatic ecosystem, while also meeting the fitness-for-use requirements of the other recognised water user groups[160] downstream of that point. However, the selected RWQO/ WQPL might also restrict the type and extent of water use upstream of that point. Water uses are addressed in **Section 3.2.2.2.3** and include uses such as the discharge of water containing waste (using some of the allocatable water quality[3]) or taking water from a water resource (using some of the dilution capacity) [DWAF, 2006d]. The purpose of the RWQOs/ WQPLs, thus, are to provide greater detail upon which to base the management of water quality, including eutrophication, which is aimed at achieving and sustaining compliance with determined and gazetted RQOs [DWAF, 2006b].

When determining RWQOs/ WQPLs, the following is implied:

- In the absence of a high confidence determination of RWQOs/ WQPLs and proper motivation, deterioration in water quality from the present state may not be accepted;
- In areas of deteriorated water quality, the quality should be improved from an Ecological Category of *"E/F"* to an ecological category of *"D"* and a management class of "Heavily used" (as a minimum);
- RWQOs/ WQPLs should be determined to (as a minimum) meet the Ecological and Basic Human Needs Reserve (or better);
- In cases where the water quality requirements of other water users are stricter than those of the aquatic ecosystem/ Ecological Reserve, the strictest water quality requirements will apply; and
- The default rule for the aquatic ecosystem, in the absence of a Reserve, and the other water users is that the minimum desired category should be *"Tolerable"*.

[178] Refer to **Section 3.1.2.4.1, Part 3**: Confirmation of the water quality constituents of concern and catchment pressures.
[179] Refer to **Section 3.1.2.4.6, Part 3**: Establishment of geographical water quality management strategies and thematic plans.
[180] Refer to **Section 3.1.2.1.6, Part 3**: Examination of historic and current point and diffuse impacts.
[181] Refer to **Section 3.1.2.1.5, Part 3**: Evaluation of the historic and current resource quality.
[182] Refer to **Section 3.1.2.4.1, Part 3**: Confirmation of the water quality constituents of concern and catchment pressures.
[183] Refer to **Section 3.1.2.1.6, Part 3**: Examination of historic and current point and diffuse impacts.

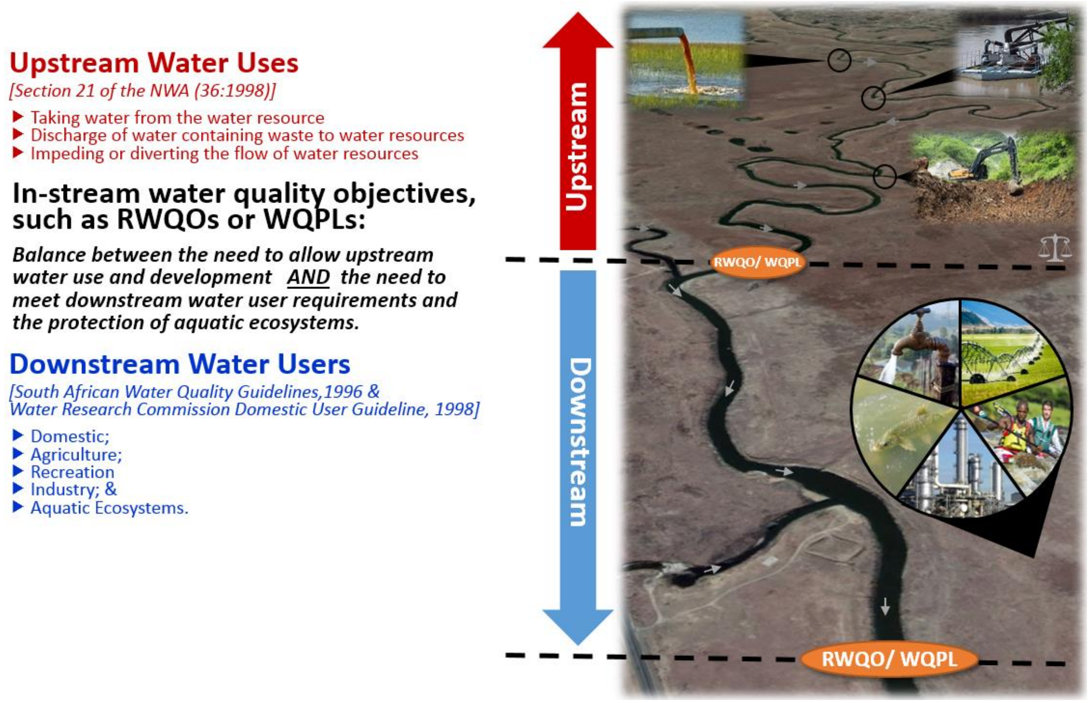

FIGURE 43: In-stream water quality objectives in support of sustainable development.

3.1.2.3.2 Determination of Waste Load Objectives

Waste Load Objectives (WLOs) refer to load targets that are determined for any water quality constituent of concern. For the purpose of this strategy, reference will be made to Nutrient Load Objectives (NLOs) that represent load targets for any phosphorus or nitrogen compounds[28] of concern.[184] NLOs are determined by balancing nutrient load *"targets"* with the technical, economic and administrative practicalities of achieving these *"targets"*. As such, the NLO constitutes an extension of the in-stream water quality objective[72] (*i.e.* the RWQO, WQPL and/or RQO)[185] within that management unit (**FIGURE 44**), and forms a link with the allocation of water quality,[186] and the establishment of the geographical water quality management strategies and thematic plans.[187] NLOs, *per se*, are not source- or sector-specific, but are determined by the DWS, or the CMA, on a geographical sub-catchment basis (*e.g.,* a phosphorus load reduction target for the catchment of an eutrophic impoundment), up to the WMA level, in the case of neighbouring WMAs that share water resources. NLOs must aim to phase-in giving effect to the designated in-stream water quality objectives within a five-year timeframe.

NLOs outline incremental nutrient load targets predominantly for surface water resources in any geographical area, usually in sub-catchments up to WMA level, at the sites where in-stream water quality objectives have been determined. NLOs, as a rule, are not determined for groundwater, because of the application of the Precautionary Principle to groundwater protection.[188] NLOs outline what needs to be done to realise in-stream water quality objectives, but not who or how this must be done. The latter aspects are addressed through the allocation of water quality[189] and the establishment and

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[184] Refer to **Section 3.1.2.4.1, Part 3**: Confirmation of the water quality constituents of concern and catchment pressures**.**

[185] Although NLOs can be conservative in nature, or take account of multiple factors, such as seasonality, it is imperative that the NLOs give effect to the relevant in-stream water quality objectives.

[186] Refer to **Section 3.1.2.4.3, Part 3**: Reconciliation and allocation of water quality.

[187] Refer to **Section 3.1.2.4.6, Part 3**: Establishment of geographical water quality management strategies and thematic plans.

[188] Refer to **POLICY STATEMENT 4**: The application of the Precautionary Principle.

[189] Refer to **Section 3.1.2.4.3, Part 3**: Reconciliation and allocation of water quality.

implementation of the geographical water quality management strategies and thematic plans.[190] The NLOs, therefore, specify incremental nutrient load reductions (in stressed sub-catchments), or potential for increases (in unstressed sub-catchments), required to realise water user and use needs. NLOs may also indicate that total incremental nutrient loads should be maintained in the face of increasing development in the catchment.[191] For further practical information on the topic, see **CASE STUDY 1** on Total Maximum Daily Loads (TMDLs).

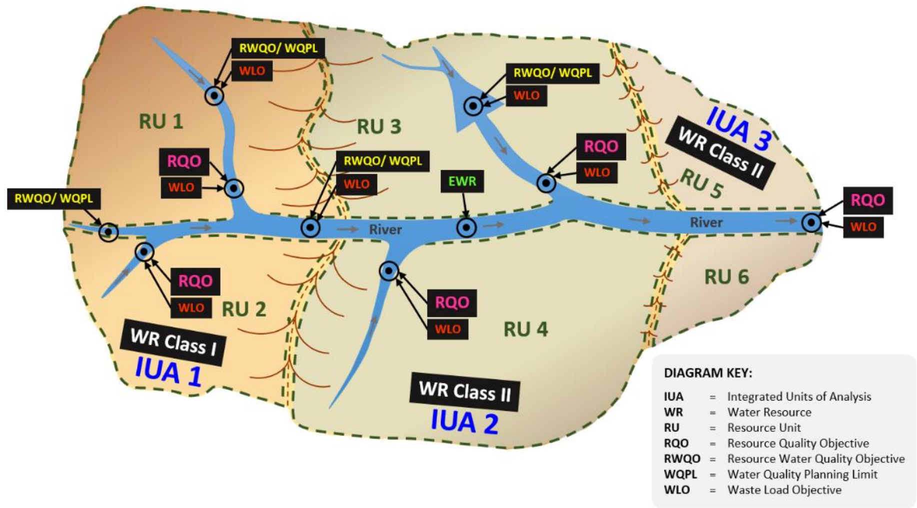

FIGURE 44: In-water resource water quality objectives and Waste Load Objectives.

In addition, the process of determining NLOs need not be based on quantifiable cause-effect relationships. NLOs can be based on simple heuristic understandings of the likely effects and feasibility of specific nutrient load reductions (or increases), or on previous modelling studies[192] of the likely effects of given changes in nutrient-loading[102]. The difference between the current state, and the in-stream water quality objective and NLO indicates the overall reduction, or increase, in nutrient concentrations and loads that should be considered.

In stressed catchments, in-stream water quality objectives will differ significantly from the current state, and considerable load reductions may be required to realise the desired in-stream water quality objectives. Many of the water resources in these catchments are also likely to have a lower water resource MC, and hence less stringent source directed measures and controls. It is, therefore, possible that additional catchment-specific standards and management practices will be required to meet relevant in-stream water quality objectives. In these cases, the economic and technical feasibility of NLOs will have to be carefully weighed against the likely impacts of nutrient load reduction. The management emphasis will be on assessing the overall nutrient load reductions required to give effect to any in-stream water quality objectives. This may require detailed assessments of the likely effects of nutrient load reductions on the downstream trophic status of surface water resources.[193]

In threatened catchments, NLOs are likely to specify that there should be no overall increase in nutrient-loading. This need not prevent further development of the catchment, but rather indicates that development in the catchment must be balanced by reductions in nutrient-loading elsewhere in the

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190 Refer to **Section 3.1.2.4.6, Part 3**: Establishment of geographical water quality management strategies and thematic plans.

191 Refer to **Section 3.1.2.2.3, Part 3**: Water quality forecasting, trends analysis and scenario definition.

192 Refer to **Section 3.1.2.1.2, Part 3**: Examination of existing and available information.

193 In a series of projects, undertaken between 2004 and 2015, to illustrate the value of a load-based approach for South Africa, loads were *inter alia* modelled (using forward and reverse annual time-step modelling) in a suite of 30 variously impacted reservoirs. Required load reductions, to bring these reservoirs into a mesotrophic state, indicated a range in load reduction of the order of 50 – 75% [Pers. coms. Harding, 2022].

catchment or nutrient load off-setting.[194] The management emphasis in these cases will, therefore, be on allocating nutrient loads to different sectors according to a water quality allocation schedule.[195]

In unstressed catchments, NLOs will specify the potential increases in nutrient-loading that may be accommodated without threatening the relevant in-stream water quality objectives. However, this is not a free licence to increase nutrient-loading, and proposed increases in nutrient-loading should only be considered if there are clear social and economic benefits to the catchment as a whole, while also considering the natural growth in the catchment, as well as any proposed developments that may occur in future.[196]

CASE STUDY 1: The *"Plan"* stage – The purpose of Total Maximum Daily Loads (TMDLs).

A *Total Maximum Daily Load* (TMDL) is a regulatory term in the United States Clean Water Act that identifies the maximum amount of a pollutant load that a waterbody can receive while still meeting water quality objective concentrations. The Clean Water Act requires that state environmental agencies determine TMDLs for impaired water resources and that the United States Environmental Protection Agency (EPA) review and approve, or disapprove, those TMDLs. Because both state and federal governments are involved in determining TMDLs, the TMDL Program is an example of cooperative federalism. If a state does not take action to determine TMDLs, or if the EPA disapproves state determined TMDLs, the EPA is responsible for issuing TMDLs. The EPA published regulations in 1992 on TMDL establishing procedures. The application of TMDLs has broadened significantly in the last decade to include many watershed-scale efforts, including the Chesapeake Bay TMDL. TMDLs identify all point and diffuse source pollutants within a watershed. The Clean Water Act requires states to compile lists of waterbodies that do not fully support beneficial users such as aquatic life, fisheries, the domestic water sector, recreation, industry, or agriculture; and to prioritize those water bodies for TMDL development **[Garvin & Enck, 2010]**.

The calculation of a TMDL is as follows: **TMDL = WLA + LA + MOS**

where **WLA** *is the waste load allocation to point sources*;
LA *is the load allocation to diffuse sources*; and
MOS *is the margin of safety*.

3.1.2.3.3 Determination of statutory Resource Directed Measures

During September 2010, in support of Chapter 3 of the NWA (36:1998) which stipulates the requirement for adequate protection and effective management of water resources, the DWS promulgated regulations prescribing a Water Resources Classification System (WRCS). The WRCS provides an outline for the determination of RDMs. These measures are aimed at maintaining the desired state of water resources, by setting, over a period,

- the Water Resource Class (MC) in Integrated Units of Analysis (IUAs)[75];
- the Reserve; and
- the RQOs for each significant water resource in Resource Units (RUs)[126].

The classifying of water resources considers the social, economic and ecological landscape in a catchment in order to assess the costs and benefits associated with use and development *versus* protection of the water resource. As such, the classification process is not carried out in isolation, but is integrated within the overall planning for water resource protection, development and use. The purpose of the water resource MC is to stipulate desired levels of protection in terms of *Class I* (minimally used), *Class II* (moderately used), or *Class III* (heavily used); to ensure long-term sustainable water resource use; to provide regulatory certainty and a framework within which other goals (*i.e.,* RQOs and the Reserve) can be determined; and to*, inter alia*, allow for the measurement of regulatory performance and compliance.

Section 3, NWA (36:1998) requires that the Reserve be determined for water resources, *i.e.,* the quantity, quality and reliability of water needed to sustain both *basic human needs* (Basic Human Needs Reserve)

[194] Refer to **POLICY STATEMENT 2**: The Mitigation Hierarchy for decision-making on eutrophication.
[195] Refer to **Section 3.1.2.4.3, Part 3**: Reconciliation and allocation of water quality.
[196] Refer to **Section 3.1.2.2.3, Part 3**: Water quality forecasting, trends analysis and scenario definition.

and *aquatic ecosystems* (Ecological Reserve), so as to meet the requirements for economic development without seriously impacting on the long-term integrity of ecosystems. It, therefore, is imperative that the Reserve must be determined and that the requirements be met, before other economic activities can be satisfied, as it is the only right to water in terms of the NWA (36:1998).

The Ecological Reserve, also referred to as the Ecological Water Requirements[44] (EWR), can be applied to eutrophication impacts in river reaches (**FIGURE 45**), although it must be kept in mind that this RDM was designed for river reaches, with the exclusion of impoundments, as they were considered as unnatural systems. It is defined as the quantity and quality of water necessary to protect aquatic ecosystems and to secure ecologically sustainable development and use of the relevant water resource. Water flow, water quality and geomorphology are the main drivers of EWRs and the habitat (vegetation) and biota (fauna) being responses. The implementation of the Ecological Reserve consists of both the physical implementation of the flow requirements, as well as the monitoring and management of water quality, habitat and biota. Eutrophication is one of the prevalent water quality issues in South Africa, and effective eutrophication management is required to meet the Reserve.

RQOs[125] are *"clear goals relating to the quality of the relevant water resources"*. RQOs are both descriptive statements and attendant numerical values for a range of water resources throughout WMAs, *i.e.* narrative and qualitative statements that describe the overall objectives for the Resource Unit[126] [DWAF, 2006b]. They define goals to protect water resources and ensure alignment to the MC of the water resources. In determining the RQOs, it is important to recognise that different water resources will require different levels of protection.

Since the inception of the WRCS in September 2010, DWS has conducted Reserve, Classification and RQO studies across the country. In order to give effect to the Eutrophication Management Strategy, the implementation of these statutory RDMs have to be realised.

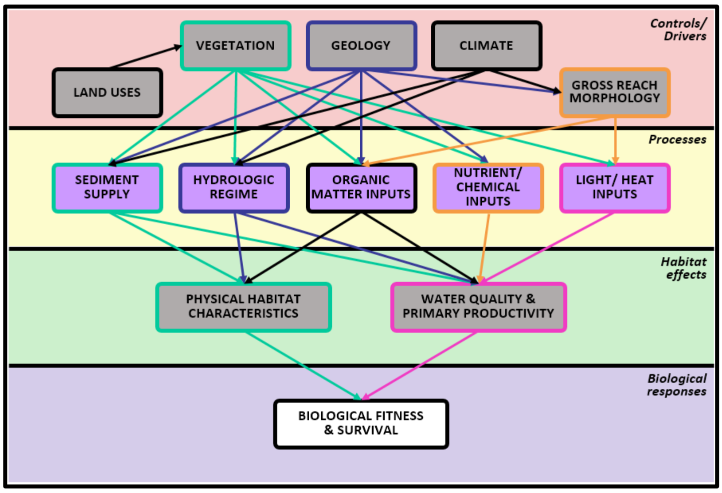

FIGURE 45: The Ecological Water Requirements components of the Reserve [Beechie & Bolton, 1999].

3.1.2.3.4 Determination of remediation objectives for pollution sources and water resources

The presence of legacy point and diffuse nutrient sources,[197] and residual impacts on water resources and associated aquatic ecosystems, which resulted from historic anthropogenic eutrophication[198] have been identified and assessed during the catchment assessment. The quantification of legacy point and diffuse

[197] Refer to **Section 3.1.2.1.6, Part 3**: Examination of historic and current point and diffuse impacts.
[198] Refer to **Section 3.1.2.1.5, Part 3**: Evaluation of the historic and current resource quality.

nutrient loads has been undertaken as part of the waste load accounting,[199] which, together with information, as generated through the allocation of water quality,[200] must inform the determination of remediation objectives for such legacy point and diffuse nutrient sources. Remediation objectives for residual impacts on water resources and associated aquatic ecosystems must be informed by the Reserve, if available.[201] The remediation objectives must be used to shape the establishment of geographical water quality management strategies and thematic plans.[202]

3.1.2.4 Intervention planning

"A goal without a plan is just a wish!" Author: Antoine de Saint-Exupéry

The end-purpose of eutrophication-focused intervention planning[203] is to map out desired ways forward, in the form of geographic water quality management strategies and/or thematic plans. These strategies and plans specify implementation details for water quality management, including different types of interventions to address eutrophication challenges, and can also be utilised to track implementation progress. Intervention planning, generally, includes the following steps [adapted from DWAF, 2003b]:

3.1.2.4.1 Confirmation of the water quality constituents of concern and catchment pressures

Historic and *status quo* concentration[204] and waste load[205] information, together with water quality intelligence gained through water quality forecasting,[206] must be compared to relevant in-resource water quality objectives and WLOs[207] to confirm all water quality constituents of concern and to select indicators for monitoring.[208] Additional and follow-up assessments over a period may be required to evaluate potential emerging pollutants. Spatial and temporal water quality and load profiles must be produced for all relevant Management Units and explained by indicating likely point and diffuse causes. These pressures must be ranked according to their observed and projected impacts to facilitate scenario evaluation and to guide the prioritisation of interventions and management options analysis.[209]

3.1.2.4.2 Scenario evaluation and management intervention options analysis

Sound eutrophication management decisions often rely on the ability to predict outcomes of streamflow and nutrient-loading along different river reaches, and for different scenarios of land and water use in the catchment. Various predictive approaches are available for the evaluation of eutrophication management scenarios, ranging from process-based catchment models to rule-based methods, through to simple regression-based formulas.

The information *"mosaic"*, created through the catchment assessment, and the value added through forward planning and management goal setting, allows for a management-oriented analysis of potential future water quality trends in space and time. It should be borne in mind that, like all projections, various degrees of uncertainty would be present in the prediction of nutrient-loading and the associated effects

[199] Refer to **Section 3.1.2.2.2, Part 3**: Waste load accounting.
[200] Refer to **Section 3.1.2.4.3, Part 3**: Reconciliation and allocation of water quality.
[201] Refer to **Section 3.1.2.3.3, Part 3**: Determination of statutory Resource Directed Measures.
[202] Refer to **Section 3.1.2.4.6, Part 3**: Establishment of geographical water quality management strategies and thematic plans.
[203] Refer to **POLICY STATEMENT 14**: Water resource assessment and planning to inform decision-making.
[204] Refer to **Section 3.1.2.1.5, Part 3**: Evaluation of the historic and current resource quality.
[205] Refer to **Section 3.1.2.2.2, Part 3**: Waste load accounting.
[206] Refer to **Section 3.1.2.2.3, Part 3**: Water quality forecasting, trends analysis and scenario definition.
[207] Refer to **Section 3.1.2.3, Part 3**: Goal setting.
[208] Refer to **Section 3.3, Part 3**: The *"check"* stage.
[209] Refer to **Section 3.1.2.4.2, Part 3**: Scenario evaluation and management intervention options analysis.

on trophic conditions and that a wide range of sensitivity analyses of the predictions in response to variations of controlling variables should form a standard part of the scenario evaluation.

Feasible scenarios[210] must be paired with potential management and intervention options, and screened by applying pre-defined criteria. This is done in order to ensure that the evaluations are comparable, and to make the ranking of scenarios and eutrophication management options, in sequence of feasibility, possible. Scenarios and management options screening criteria could include:

- Economic considerations;
- Socio-political considerations;
- Ecological considerations;
- Recreational, cultural and/or eco-tourism aspects;
- Legal considerations;
- Technical viability (physical and operational); and
- Statutory and institutional responsibilities, including co-operative arrangements.

Options are mostly compared through cost-benefit analysis[30].

3.1.2.4.3 Reconciliation and allocation of water quality

The current excessive nutrient-loading trajectories, observed in many of our water resources, are exceeding the ability of such water resources to assimilate nutrients without compromising fitness-for-use. In order to arrest this deteriorating trend, it has become critical that demands for allocatable water quality must be balanced with availability.[211] The mechanism that is used to unpack the demands for water quality and to reconcile water quality, is the allocation of water quality through a *"water quality allocation schedule"* that forms the foundation of the *"water quality allocation plan"*.

The *"water quality allocation plan"* is aligned with the Water Allocation Plan required, as part of Catchment Management Strategies (CMS) [NWA, 1998, S.9(e)]. In the context of eutrophication management, the water quality allocation plan, through the water quality allocation schedule, must allocate the available incremental nutrient load, defined by the NLOs, to different water user sectors on a template of *"Management Units"*. The water quality allocation plan, further, must specify and link to the necessary source or remediation directed measures and controls, which must be adopted for each sector, and which must address both point and diffuse nutrient sources, in order to achieve the desired nutrient-loading.

This approach, therefore, allocates nutrient load targets, through the NLOs, to parts of catchments. These incremental sub-catchment NLOs are then re-allocated to specific sectors or sources within the water quality allocation plan. As the water quality allocation plans are developed in close co-operation with stakeholders from the relevant sources and sectors, this process forces stakeholders to think within the wider catchment perspective when allocating load targets for specific sectors or sources.

The water quality allocation plan may relate to point and diffuse source impacts, and in-stream management, including suitable reservoir release operating rules,[212] in-stream rehabilitation and restoration,[213] and ecological water requirements.[214] The water quality allocation plan, further, plays an important role in nutrient-loading off-sets[215] and informs the publicly accessible register of all offsets. The water quality allocation plan has a central relationship with, and forms an important part of the

[210] Refer to **Section 3.1.2.2.3, Part 3**: Water quality forecasting, trends analysis and scenario definition.

[211] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives Approach applied to eutrophication management.

[212] Refer to **Section 3.1.2.4.5, Part 3**: Identification of possible implications for water resource systems operation.

[213] Refer to **Section 3.4.2.1, Part 3**: Retroactive action.

[214] Refer to **Section 3.1.2.3, Part 3**: Goal setting.

[215] Refer to **POLICY STATEMENT 2**: The Mitigation Hierarchy for decision-making on eutrophication.

geographical water quality management strategies and thematic plans that must be established,[216] and provides an indication of the potential for additional ecologically sustainable development, if any, to support further socio-economic development.

3.1.2.4.4 Identification and development of linkages with land use planning and management

Catchment eutrophication management is part of a wider planning and development environment, which is affected by the fragmentation that characterises South Africa's water, land-use, and environmental legislation and administration. Whereas the institutional linkages, that are required to counter this fragmentation, must be addressed during the catchment assessment study.[217] It is equally important to focus on the fragmented statutory arrangements for spatial, land-use and infrastructural development planning that potentially affect anthropogenic eutrophication. Any potential synergy with national, provincial, regional and local planning processes to limit the effects of anthropogenic eutrophication must be identified and developed, through cooperative governance and consultation.[218] The projected growing nutrient-loading trends due to population growth and potential physical developments in the catchment must be identified, and development planning and land use management must be influenced, in the interest of water security. The identification and development of linkages with land use planning and management must be transferred to the establishment and implementation of the geographical water quality management strategies and thematic plans.[219]

3.1.2.4.5 Identification of possible implications for water resource systems operation

The DWS is responsible for the development and maintenance of water resource system operating rules for reservoirs, systems of interlinked reservoirs and large schemes, which support major economic zones, as well as for smaller reservoirs and systems that supply water to towns and rural areas. These operating rules are often based on complex decision support systems, which include stochastic simulation models that carry out monthly simulations and that advise users of the risk of entering a restriction zone in future so that informed decisions can be made. Such operating rules, for instance, address the transfer of water between water resources, the conjunctive use of surface and groundwater, the dilution of water pollution or the use of desalination plants during periods of drought.

The regulation of developed surface water resources has the potential to either adversely affect, or to improve aquatic ecosystem health. Flow manipulation has proved to be a promising intervention to combat eutrophication in some developed river systems, because it focuses on residence time and stratification[139] as prominent drivers of algal blooms [Davis & Koop, 2006; Davis & Koop, 2001]. Greater attention must be given to flow management and systems operation as a means of reducing primary production[115] levels and mimicking natural flow situations[220] in downstream water resources, particularly in the case of highly regulated river systems. The reservoir discharge pattern, rather than releasing more water, may prove to be an effective short to medium-term management measure. In the long term, management must shift towards addressing the causes of anthropogenic eutrophication, rather than dealing with the symptoms.

3.1.2.4.6 Establishment of geographical water quality management strategies and thematic plans

The geographical water quality management strategy assembles the elements of integrated water quality management to suitably address any relevant eutrophication challenges and priorities, at the level of sub-catchments (Management Units) and/or WMAs (**FIGURE 46**). The geographical water quality management strategy and/or sub-strategies are supported by the establishment of any number of water

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[216] Refer to **Section 3.1.2.4.6, Part 3**: Establishment of geographical water quality management strategies and thematic plans.

[217] Refer to **Section 3.1.2.1.1, Part 3**: Stakeholders and role-player identification and consultation.

[218] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

[219] Refer to **Section 3.1.2.4.6**: Establishment of geographical water quality management strategies and thematic plans.

[220] Refer to the Reserve, as per **Section 3.1.2.3.3**.

quality management plans required to address particular water quality management related themes, such as to combat and manage eutrophication and the allocation of water quality.

Collectively, the geographical water quality management strategies and thematic plans must ensure that the vision[221] and relevant management goals[222] are operationalised through the implementation and tracking[223] of the selected management intervention options.[224] These intervention options may include a variety of source [225] and remediation [226] directed, and cooperative land use development and management[227] measures and controls, water resource systems operating rules,[228] and the roll-out of infrastructure solutions[229] to limit excessive primary production in water resources. In the absence of geographical water quality management strategies and thematic plans, and until these strategies and plans can be developed for implementation, *ad hoc* day-to-day eutrophication management activities must continue. In the case of fully operational CMAs, the geographical water quality management strategies and thematic plans, described here, will form part of their Catchment Management Strategies (CMSs) and supporting documentation.

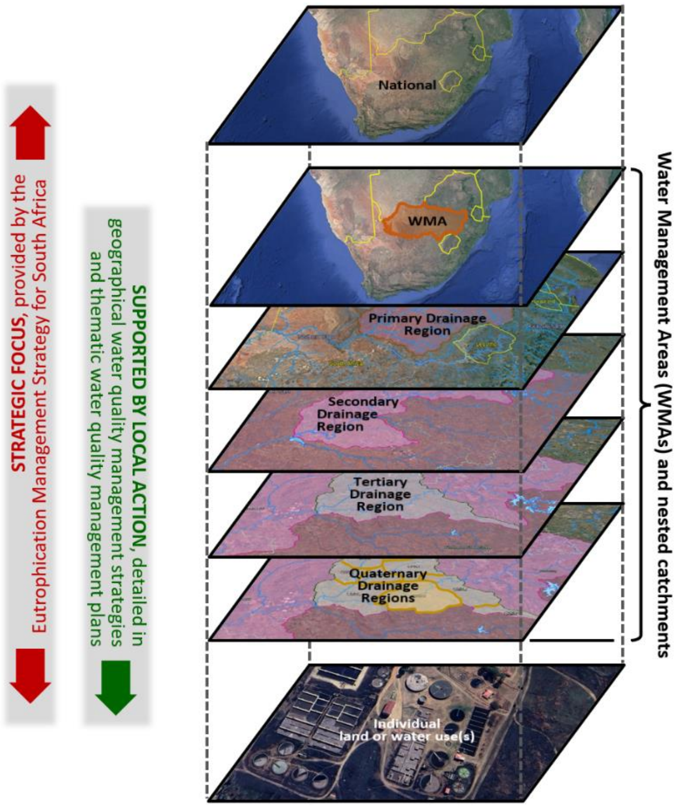

FIGURE 46: The Eutrophication Management Strategy for South Africa must ideally be *"regionalised"* through geographical water quality management strategies and/or thematic plans, in order to ensure informed local action through holistic and integrated eutrophication management.

221 Refer to **Section 3.1.2.2.4, Part 3**: Visioning to propose levels for water resource protection.
222 Refer to **Section 3.1.2.3, Part 3**: Goal setting.
223 Refer to **Section 3.1.2.4.8, Part 3**: Implementation coordination and maintenance.
224 Refer to **Section 3.1.2.4.2, Part 3**: Scenario evaluation and management intervention options analysis.
225 Refer to **Section 2.1, Part 3**: Source Directed Management.
226 Refer to **Section 2.3, Part 3**: Remediation Directed Management.
227 Refer to **Section 3.1.2.4.4, Part 3**: Identification and development of linkages with land use planning and management.
228 Refer to **Section 3.1.2.4.5, Part 3**: Identification of possible implications for water resource systems operation.
229 Refer to **Section 3.1.2.4.7, Part 3**: Infrastructure planning.

3.1.2.4.7 Infrastructure planning

Even though nature-based solutions are preferred,[230] built or hard infrastructure must often be employed to address point and diffuse nutrient challenges. In many cases, intervention options analysis[231] may prefer the establishment of built or hard infrastructure to address eutrophication-related challenges. The absence of necessary infrastructure solutions to deal with waste and wastewater[151] with a high nutrient or organic character, is likely to contribute to accelerated anthropogenic eutrophication. Infrastructure to address nutrient pollution causes and effects, include waste, wastewater and water treatment, waste disposal and pollution control facilities; networks of water reticulation, reservoirs and pumping systems; stormwater control infrastructure; and much more. These infrastructure solutions are utilised by the three spheres of government and by the private sector to prevent, manage and/or treat nutrient rich pollution-related causes and effects. Government funded infrastructure planning investigations must be conducted in an incremental manner to limit spending on non-feasible projects. To achieve this, planning investigations are usually conducted at three levels to ensure that non-viable projects are identified early on. These planning investigation levels are:

- **Reconnaissance:**
The main objective of this level of investigation is to determine, at the lowest investigation cost, whether the proposed infrastructure project indeed has development potential;

- **Pre-feasibility:**
The main objective of this level of investigation is to compare one project with another in order to select the preferred project for further investigation. Comparisons are not only made on economic grounds, but also on environmental grounds; and

- **Feasibility:**
The main objective of this level of investigation is to demonstrate technical feasibility and economic viability. The feasibility study, therefore, is conducted at a high level of detail. The feasibility report would also be used for Environmental Impact Assessment (EIA) purposes. The feasibility report is the primary source document to be used during detailed design.

Infrastructure planning includes timeous and vital planning to address increasing demands for wastewater handling capacity to keep-up with development. Vandalism of infrastructure must be considered and, as far as is possible, prevented.

3.1.2.4.8 Implementation coordination and maintenance

The implementation and maintenance of the geographical water quality management strategies and associated thematic plans (or the CMS - in the case of operational CMAs), specifically with respect to the management of eutrophication,[232] is vital to limit excessive nutrient-loading and to improve the trophic status of many water resources. The establishment of a Strategy Steering Committee (SSC) to oversee implementation and maintenance must be considered. The SSC will have to meet regularly to effectively track and monitor strategy roll-out and updating.[233] The SSC will have to comprise relevant authorities, key land and water user sectors, key stakeholders, and selected experts.

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[230] Refer to **POLICY STATEMENT 8**: Nature-based solutions.

[231] Refer to **Section 3.1.2.4.2, Part 3**: Scenario evaluation and management intervention options analysis.

[232] Effective implementation and maintenance of the geographical water quality management strategies and associated thematic plans is dependent on, and linked to the *"check"* stage (Section 3.3) for data, information and performance tracking.

[233] Refer to **Section 3.3, Part 3**: The *"check"* stage.

3.1.3 *Spatial scale of implementation*

Assessments[234] can be conducted on an *ad hoc* basis or regularly. Assessments should be done on different geographical scales, ranging from the transboundary scale to national, regional, catchment or sub-catchment, and to a local scale.

The operational strategies, being part of the *"plan"* stage in the eutrophication management framework, can be conducted for different geographical scales; ranging from the transboundary scale to national, regional, catchment or sub-catchment, and to a local scale.

Assessments, forward planning, goal setting and intervention planning must take place at spatial scales that appropriately balance–

- the complexities of the area in question;
- environmental integration; and
- the need to devolve water quality management to the lowest practical and appropriate level.

3.1.4 *Temporal scale of implementation*

The operational strategies, being part of the *"plan"* stage in the eutrophication management framework, can be conducted on an *ad hoc* basis or regularly, depending on the purpose. **TABLE 18** gives a summary of potential actions, in the *"plan"* stage, which must be considered, to improve the trophic status of water resources:

TABLE 18: Operational actions to strengthen the *"plan"* stage of the eutrophication management framework.

	SHORT TERM
1	Determine statutory RDMs, *i.e.*, Water Resource Class(es) (and RQOs/ Reserves), for significant water resources that are still outstanding;
2	Determine RWQOs/ WQPLs, based on the South African Water Quality Guidelines [DWAF, 1996], in support of statutory RDMs, specifically the RQOs;
3	Develop and roll-out the methodologies to determine NLOs; and
4	First establish and implement geographical water quality management strategies and thematic plans for three priority WMAs; followed by the establishment and implementation of water quality management strategies and plans for the remaining WMAs. Waste load accounting, goal setting, and water quality allocation plan development constitute important components of this process;
	LONGER TERM
5	Influence Water Services Development Plans (WSDPs), Integrated Development Plans (IDPs) and any other relevant strategies, plans or frameworks to reflect eutrophication management priorities and management requirements.
6	Establish and implement geographical water quality management strategies and thematic plans for the remaining WMAs.

[234] Refer to **POLICY STATEMENT 14**: Water resource assessment and planning to inform decision-making.

3.2 The *"do"* stage

Allegations are often voiced that good legislation and departmental policy, *per se,* are of little value without a methodical *"plan"* mapping out roll-out, and actual implementation by *"doing"* what is specified in the *"plan"*. Therefore, a "plan" stage without a "do" stage is as meaningless as a "do" stage without a "plan" stage. These two stages in the eutrophication management framework are interdependent and must coexist.

The *"do"* stage in the eutrophication management framework is about application, which must turn eutrophication management strategy into *"actions"* and *"results"*, in order to accomplish the Eutrophication Management Goal, objectives and associated policy imperatives.

Altogether the *"do"* stage, in the eutrophication management framework, must–

- give effect to the goals that were determined,[235] and the strategies and thematic plans that were established, during the *"plan"* stage in the eutrophication management framework, in order to manage eutrophication in catchments;
- protect the aquatic ecosystem and other receiving water users by ensuring that compliant waste and wastewater return to water resources;[236]
- promote incentive-based regulation;[237]
- be rolled out in a cooperative manner,[238] collaborating with other regulators;
- address eutrophication challenges in a holistic[239] and *"cradle-to-grave"* fashion by addressing pollution as close as possible to its source or origin;[240]
- make suitable use of the management instruments for environmental compliance;[241]
- facilitate pollution avoidance, prevention and minimisation, in accordance with policy;[242] and
- promote the application of nature-based solutions[243] and the implementation of the BPEO,[244] as may be appropriate.

The *"do"* stage, in the eutrophication management framework, focuses on three linked operational strategies, as depicted in **FIGURE 47**. It is suggested that these three strategies should initially receive the bulk of the attention. These three strategies, dealing with (1) *"Best management practice"*; (2) *"Water use authorisation and conditional regulation"*; and (3) *"Incentive-based regulation"* can be expanded, as may be necessary, and rolled out, in the interest of combatting excessive eutrophication. More operational strategies may be identified and developed, under the "do" stage in the eutrophication management framework, in the future.

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[235] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives Approach applied to eutrophication management.
[236] Refer to **POLICY STATEMENT 3**: The Differentiated Approach for the control of excessive nutrient-loading.
[237] Refer to **POLICY STATEMENT 7**: Incentive-based regulation.
[238] Refer to **POLICY STATEMENT 19:** Cooperative eutrophication management.
[239] Refer to **POLICY STATEMENT 10**: Holistic eutrophication management.
[240] Refer to **POLICY STATEMENT 6**: A life cycle view on nutrient-loading.
[241] Refer to **POLICY STATEMENT 1**: Application of management instruments for environmental compliance in eutrophication management.
[242] Refer to **POLICY STATEMENT 2**: The Mitigation Hierarchy for decision-making on eutrophication.
[243] Refer to **POLICY STATEMENT 8**: Nature-based solutions.
[244] Refer to **POLICY STATEMENT 9**: The application of the Best Practicable Environmental Option.

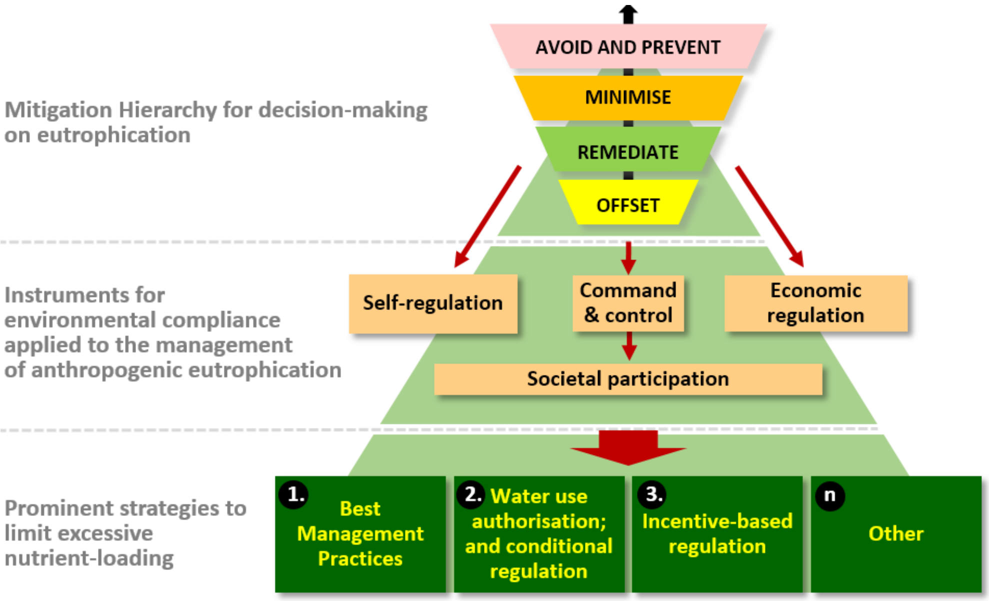

FIGURE 47: Limiting nutrient-loading through best management practices; water use authorisation and conditional regulation; and incentive-based regulation.

These three operational strategies, and their purpose and composition, are narrated in **TABLE 19**:

TABLE 19: The operational strategies, in the "do" stage of the eutrophication management framework, and their composition.

OPERATIONAL STRATEGIES AND PURPOSE		KEY COMPONENT(S)
1. Best management practice	*To apply management practices that limit excessive nutrient-loading.*	Best available technology;
		Cleaner technology and cleaner production
		Conversion of environmental problems into socio-economic and developmental solutions;
		Waste reduction, recycling and reuse;
		The use of buffer zones; and
		The use of constructed wetlands.
2. Water use authorisation and conditional regulation	*To enforce conditional authorisations and other regulatory requirements that limit excessive nutrient-loading.*	National Water Pollutant Register
		Waste Discharge Standards (WDSs);
		Water use;
		Registration of water use;
		Lawful water use;
		Schedule 1 water use;
		General Authorisations;
		Existing Lawful water Use (ELU);
		Water use licensing;
		Alternative authorisations;
		Diffuse pollution sources; and

OPERATIONAL STRATEGIES AND PURPOSE		KEY COMPONENT(S)
		Differentiated water use management based on risk
3. Incentive-based regulation	*To incentivise responsible behaviour that limits excessive nutrient-loading.*	Waste Discharge Charge System (WDCS);
		Administrative penalties;
		Certification Schemes;
		Water Polluter Register; and
		Eco-labelling.

3.2.1 Authority

There are a number of authorities involved in the authorisation of activities that may contribute to excessive nutrient-loading. The DWS and Catchment Management Agencies (CMAs) may generally authorise or licence water use, whereas other authorities may authorise several types of land use activities, or aspects thereof. In addition to the siloed approach to environmental authorisations, frequently raised as a hindrance to economic development, fragmented authorisation processes often also burden achieving other government goals, including the goal for eutrophication management. This is particularly evident when the other environmental authorisations are administered by authorities with non-water resource focused mandates. Additional to the establishment of the One Environmental System, which is supported, [245] regulatory cooperation between authorities, with respect to the management of anthropogenic eutrophication, must be improved.[246] Competencies (sectors), which are relevant here, include: agriculture; the environment; human settlements; infrastructure; mining; and water and sanitation. These competencies are linked to responsible authorities in Chapter 5 of Part 3 that addresses ***"Governance"***, and that gives additional resolution to the assigning of roles and responsibilities in a eutrophication management context.

3.2.2 Prescribed approaches

3.2.2.1 Best management practice

> ***"Innovation means replacing the best practices of today with those of tomorrow!"*** Author: Paul Sloane

Best management practices (BMPs), in the context of eutrophication management, are practices or methods that have been developed to be the most effective and practical means of limiting point and diffuse sources of excessive nutrient-loading, and to help with achieving the Eutrophication Management Goal, objectives and policy imperatives. The BMPs can have a catchment and water resource focus or can apply to sources of anthropogenic eutrophication. The list of important BMPs and concomitant descriptions, referenced below, by no means constitutes an exhaustive list. A portfolio of BMPs, therefore, has to be identified and BPGs developed over time to provide sectoral norms for BMPs and a comprehensive series of BPGs. One should be able to apply such BPGs to land and water use activities through cooperative management,[247] also considering making some of these BMPs, where appropriate, compulsory in future.[248] The BPGs for eutrophication management must be set up such that they promote

[245] Refer to **POLICY STATEMENT 1**: Application of management instruments for environmental compliance in eutrophication management.

[246] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

[247] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

[248] Refer to S. 26(1)(i), NWA (36:1998): *"The Minister may make regulations prescribing the outcome or effect which must be achieved through management practices for the treatment of waste, or any class of waste, before it is discharged or deposited into or allowed to enter a water resource."*, and **Annexure F** for other regulations.

the Mitigation Hierarchy for decision-making on eutrophication.[249] The categories – (1) pollution avoidance and prevention; (2) minimisation; and then (3) remediation; and, finally, (4) offsetting[53] should be utilised to structure eutrophication management BPG development per such category. Some BMPs for eutrophication management are briefly elaborated, below:

3.2.2.1.1 Best available technology

Wastewater treatment[152] technologies are generally proven for South African conditions, and a local knowledge base exists to plan, design, construct, operate and maintain a wide range of treatment technologies and WwTWs. BMPs with guidelines for smaller and conventional treatment technologies and/or WwTWs must be considered and, if merited, developed. Some of the more sophisticated technologies such as advanced oxidation, membrane desalination, *etc.* have been applied to a limited number of local projects. The South African water and waste disposal industry will need to grow capacity[250] to confidently implement and maintain some of the more advanced wastewater treatment technologies.[251] BMPs with guidelines for these treatment technologies and/or WwTWs should be considered and, if merited, developed.

3.2.2.1.2 Cleaner technology and cleaner production

"Cleaner production" has emerged as an industry initiative that is intended to minimize waste and emissions, while maximising product output and profitability. By analysing the flow of materials and energy in industrial production processes, options to minimize waste and emissions can be identified, and industry source reduction strategies can be established. Improvements of organisation and technology help to suggest better choices in the utilisation of materials and energy, to avoid waste, wastewater generation, unwanted gaseous emissions, waste heat and noise, as well as more efficient resource use, increased business profitability and competitiveness, and increased production process efficiency. *"Cleaner production"* is applicable to all businesses, regardless of size or type. In addition to the BPGs for wastewater treatment and handling, BMPs with guidelines for cleaner production and cleaner technology should also be considered and, if merited, developed.

3.2.2.1.3 Conversion of environmental problems into socio-economic and developmental solutions

In situations where pollution problems exist, an attempt must be made to exploit opportunities and to convert problems into solutions. Such opportunities may, amongst others, include recognising-

- the nature of water scarcity in South Africa and moving to waterless sanitation options for all South Africans; and
- the nature of human excreta (faeces and urine) as a resource to be utilised, particularly for fertiliser products, but also for the reclamation of important elements[49], such as phosphorus, which is a critical and a globally limited resource essential for crop production.

Opportunities to convert problems into solutions must be identified and, if merited, established through research,[252] development and wider implementation and roll-out. BMPs with guidelines must be considered to give further impetus to the conversion of specific problems into solutions.

3.2.2.1.4 Waste reduction, recycling and reuse

The discharge and disposal of waste and wastewater, including the evaporation of, and the non-beneficial irrigation with water containing waste, is in most cases a last resort. The recycling and reuse[129] of

[249] Refer to **POLICY STATEMENT 2**: The Mitigation Hierarchy for decision-making on eutrophication.
[250] Refer to **Section 4.1, Part 3**: Technical capacity building to give impetus to eutrophication management.
[251] Refer to **Section 4.2, Part 3**: Research and technology development to address eutrophication-related challenges.
[252] Refer to **Section 4.2, Part 3**: Research and technology development to address eutrophication-related challenges.

wastewater, if possible and desirable, is preferred compared to the use of potable water. Reuse and recycling strategies are of particular importance in the context of urban areas where significant volumes of wastewater are constantly being generated and discharged, after treatment, by municipal WwTWs. Potential municipal water reuse options include the irrigation of public open spaces (*e.g.* parks); sports fields (*e.g.* municipal, school and club facilities, and golf courses); and cooling (related to industry and power generation); as well as firefighting; toilet flushing; cooling systems; street cleaning; dust control; and a variety of other applications which do not require potable water [DWA, 2011a]. Reuse strategies must be cognisant of any water budget requirements that may apply. BMPs with guidelines must be identified and, if merited, developed to give further impetus to pollution minimisation.

3.2.2.1.5 The use of buffer zones

The use of buffer zones holds great promise for, *inter alia,* assisting with sediment retention; nutrient and toxins removal; the maintenance of channel stability; flood attenuation; improved groundwater recharge; provision of habitat for wildlife; the screening of adjacent disturbances; habitat connectivity; aesthetic appeal; and the control of water temperatures through the attenuation effects associated with the vegetation growing alongside water resources that affect the microclimate of stream areas nearest to stream banks [Macfarlane, et al., 2009]. Existing guidelines should be considered and, if necessary, adjusted to integrate with eutrophication management and this Strategy; and should be fully implemented as a matter of priority.

3.2.2.1.6 The use of constructed wetlands

Similar to the use of buffer zones, constructed wetlands provide an effective nature-based[253] measure for the control and management of pollution sources, such as those causing excessive nutrient-loading and anthropogenic eutrophication. A constructed wetland is an artificial system to treat municipal or industrial wastewater, greywater or stormwater runoff. Such systems consist of properly designed depressions, or basins, that contains water; substrate (such as soil, sand, gravel, rock, and organic compost materials); vascular plants[148]; and communities of microbes and aquatic invertebrates. Nutrients, sediments and litter then accumulate in the constructed system because of the low water velocities and high productivity, typical of wetlands. However, these wetlands can also get saturated and lose their nutrient removal functionality if not properly maintained.

The substrates, nutrients, sediments, and litter are important for several reasons [Davis, 1995]:

- They support many of the living organisms in wetlands;
- Substrate permeability affects the movement of water through the wetland;
- Many chemical and biological (especially microbial) transformations take place within the substrates;
- Substrates provide storage for many contaminants; and
- The accumulation of litter increases the amount of organic matter in the wetland. Organic matter provides sites for material exchange and microbial attachment, and is a source of carbon, the energy source that drives some of the important biological reactions in wetlands.

The physical and chemical characteristics of soils and other substrates are altered when they are flooded. In a saturated substrate, water replaces atmospheric gases in the pore spaces and microbial metabolism consumes the available oxygen. Since oxygen is consumed more rapidly than it can be replaced by diffusion from the atmosphere, substrates become anoxic[5]. This reducing environment is important in the removal of pollutants such as nitrogen and metals [Davis, 1995].

253 Refer to **POLICY STATEMENT 8:** Nature-based solutions.

3.2.2.2 Water use authorisation and conditional regulation

"Good regulation should be conducive to business and to customer protection!" Author: Jamie Dimon

Command-and-control, or alternatively called *"direct regulation"*, is a key approach employed by governments globally to ensure environmental compliance.[254] In the context of eutrophication management, a suite of regulatory measures should, ideally, have been available to address different types and combinations of point and diffuse sources of excessive nutrient-loading on a catchment-by-catchment basis. This, however, is not the case, and current regulatory measures mostly focus on point sources of pollution. These source directed measures and controls, are elaborated, first, below:

3.2.2.2.1 National Water Pollutant Register

Everything that happens in a catchment reflects in the quality of the water resources that flow through, or that occur within it, because the results of human activity and lifestyle ultimately end up in water resources through point and diffuse runoff impacts. Anthropogenic eutrophication is the result of nutrients that are being introduced into water resources by catchment activities. Factors, such as increasing industrialization, urbanization, intensive farming practices and climate change, amongst others, all have an impact on the potentially changing character of water pollution (**FIGURE 48**). Many emerging pollutants, being increasingly observed in water resources, potentially also contain phosphorus and nitrogen that contribute towards the occurrence of anthropogenic eutrophication. To stay abreast and to focus management action, the changing character of pollution must be observed and continuously evaluated.[255]

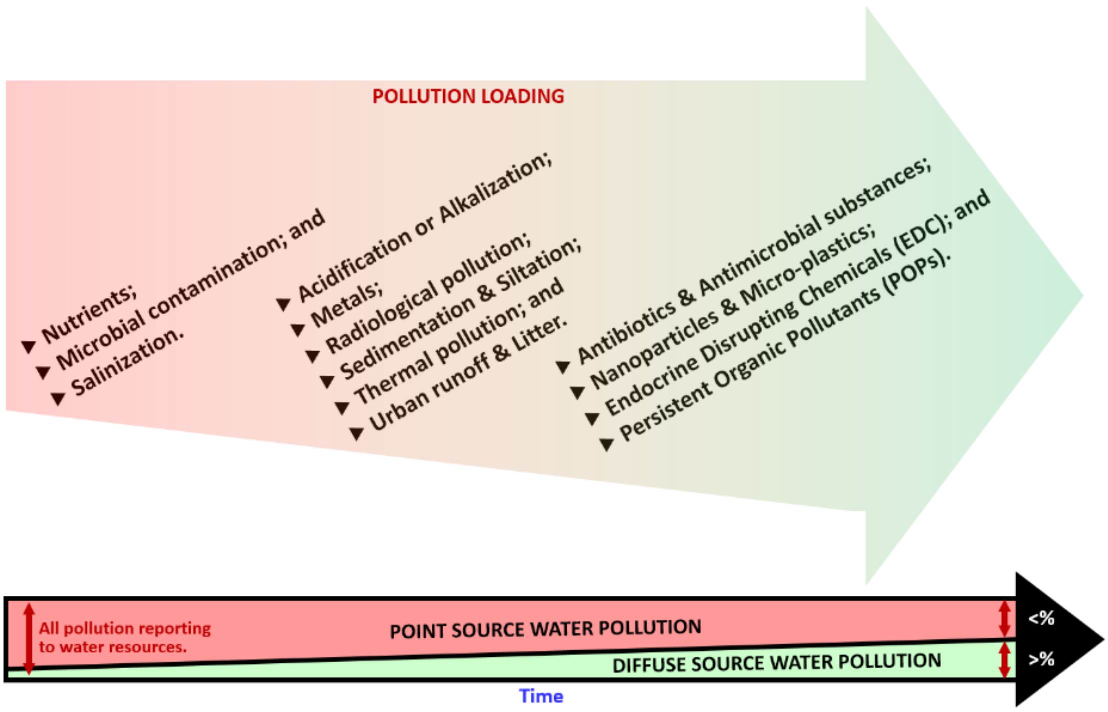

FIGURE 48: Changing character of water pollution and the introduction of emerging pollutants.

The development of a *"National Water Pollutant Register"*, in conjunction with the development of WDSs (**Section 3.2.2.2.2**) and other emission standards, such as ambient air quality and emission standards, must be considered. Such a register will provide structure to pollution control and integrated water quality

[254] Refer to **POLICY STATEMENT 1**: Application of management instruments for environmental compliance in eutrophication management.
[255] Refer to **POLICY STATEMENT 14**: Water resource assessment and planning to inform decision-making.

management in a changing environment[51], and can be utilised to identify categories of pollutants or substances that have to be dealt with in particular ways. The following pollutant or substance list categories can be considered:

- **A list of national priority substances**, which pose a national threat to receiving water users and aquatic ecosystems, and for which WDSs and, if necessary, other emission standards, such as national ambient air quality and emission standards, have to be determined to reduce or eliminate such substances in surface or groundwater, or in marine waters. The list of national priority substances must be periodically reviewed, *e.g.,* five yearly;
- **A list of WMA or sub-catchment specific priority substances**, which pose a local or regional threat to receiving water users and aquatic ecosystems only, and for which WDSs and, if necessary, other emission standards, such as provincial or local ambient air quality and emission standards, have to be determined to reduce or eliminate such substances in surface or groundwater. The list of WMA or sub-catchment priority substances must be periodically reviewed, *e.g.,* five yearly, in collaboration with CMAs;
- **A *"watch list"* containing new or emerging substances**, for which no WDSs are available, or for which little information is available, and that should be monitored for the purpose of risk determination and to determine WDSs and/or other emission standards, as may be necessary. The *"watch list"* containing new and emerging substances must be periodically reviewed, *e.g.,* five yearly and can be used, *inter alia*, to influence research and technology development priorities,[256] etc.; and
- **A list of priority hazardous substances**, for which water resources have no assimilative capacity[8] due to their persistency, liability to bio-accumulate and toxicity, or other equivalent concerns, and that need to be eliminated altogether from water resources.[257] The list of priority hazardous substances must be periodically reviewed, *e.g.* five yearly.

It is possible for hazardous substance to also appear on the lists of either national or WMA or sub-catchment priority substances. When more information becomes available, substances can be transferred from the *"watch list"* to any of the other three lists or they can be dropped. The establishment of a list of non-priority substances (*i.e.,* the *"dropped"* substances) may be considered for record purposes.

3.2.2.2.2 Waste Discharge Standards (WDSs)

The *General and Special Standards for the purification of Wastewater or Effluent*, dating back to 1984 [GN R.991, 1984], is overdue for revision – especially the Special Standard for phosphorus of 1mg/ℓ orthophosphate. Section 15 of the NWA (36:1998) compels the Minister of Water and Sanitation, the Director-General, organs of state and any Water Management Institution, when exercising powers or performing duties under the NWA (36:1998), **to give effect to any determination of a water resource MC and RQOs**, and any other requirements for complying with the RQOs.[258]

Ideally, WDSs must be determined separately for every point discharge (**FIGURE 49**) in order to ensure that compliance to such WDSs will give effect to the relevant statutory RDMs and to ensure fitness-for-use. In this way, source directed measures and controls to be applied to point discharges can be custom-fitted and directly linked with relevant receiving water resources requirements, *i.e.,* the *"RQOs and any other requirements for complying with the RQOs"*. Although, doable, such an arrangement will certainly not be practical under current circumstances, and is probably not desirable.

For this reason, it is important that a set, or sets, of appropriate uniform WDSs must be developed, in support of Source Directed Management. Uniform WDSs are essential and are useful, because they-

[256] Refer to **Section 4.2, Part 3**: Research and technology development to address eutrophication-related challenges.
[257] Refer to **POLICY STATEMENT 4**: The application of the Precautionary Principle.
[258] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives Approach applied to eutrophication management.

- can be utilised as benchmarks during the authorisation of waste and water containing waste related water uses;
- provide a practical, albeit conservative, first line and broad brushed approach to give effect to RDMs;
- complement the Mitigation Hierarchy for decision-making on eutrophication[259] and because WDSs can be used to promote precaution[260] in cases of uncertainty;
- can be referenced in waste and water containing waste related water use authorisations, potentially allowing for periodic updating of the said uniform WDSs without necessarily having to amend the water use authorisations in question, incorporating an element of flexibility to such authorisations; and
- can be administered and maintained effectively through the publication in regulations.[261]

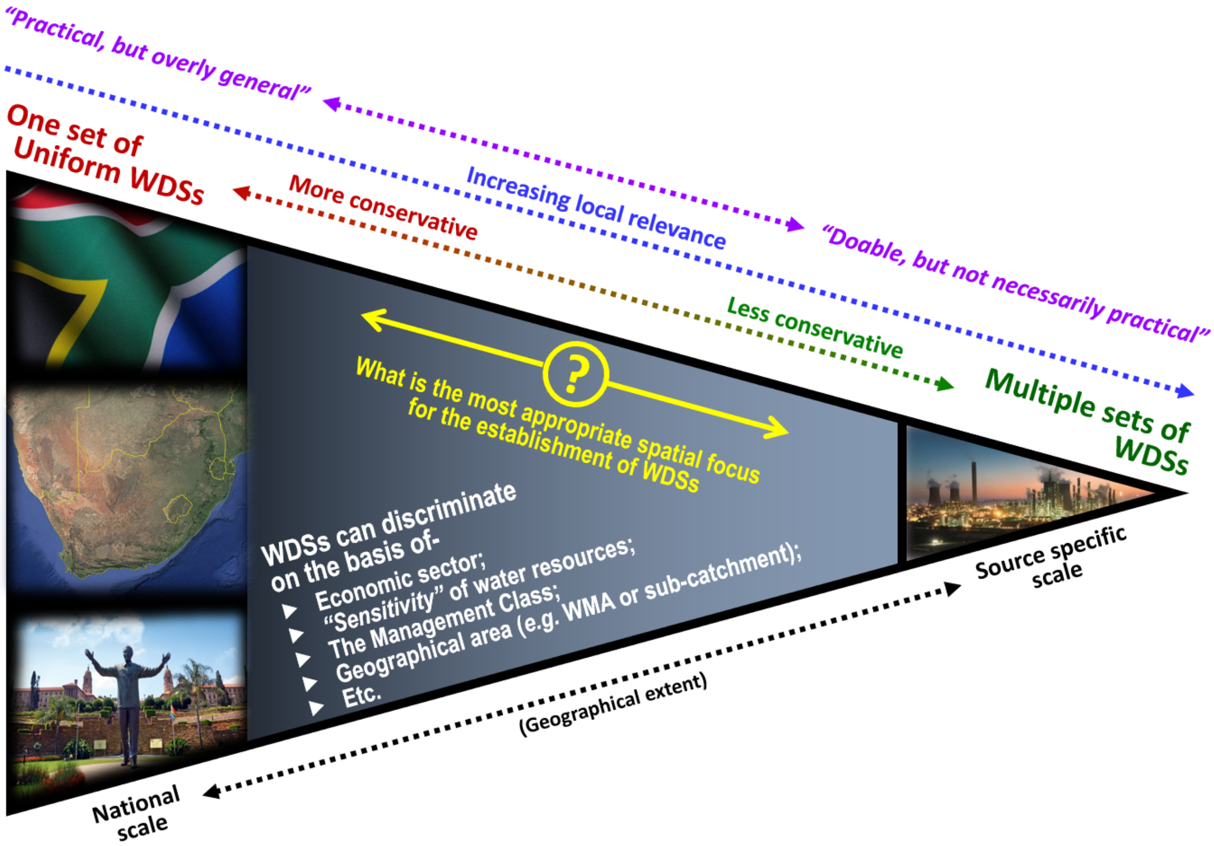

FIGURE 49: The establishment of uniform Waste Discharge Standards (WDSs) to support water use authorisation.

259 Refer to **POLICY STATEMENT 2**: The Mitigation Hierarchy for decision-making on eutrophication.

260 Refer to **POLICY STATEMENT 4**: The application of the Precautionary Principle.

261 Refer to S. 26(1)(h), NWA (36:1998): *"The Minister may make regulations prescribing waste standards which specify the quantity, quality and temperature of waste which may be discharged or deposited into or allowed to enter a water resource."*, and **Annexure F** for other regulations.

Factors that must be considered when uniform WDSs are being developed for typical water resource use scenarios, include:

- The size of the discharge;
- The size of the river;
- The water quality of the effluent;
- The catchment background or reference water quality;
- Water quality of the receiving surface water resource(s);
- The mixing ratio;
- The effects of seasonality;
- The recognised receiving water users that must be protected;
- Ecological importance and sensitivity;
- The requisite levels of water resource protection;
- Potential cumulative effects;
- The capability of treatment technologies (BPEO);[262]
- The history, and nature of the activities;
- The Mitigation Hierarchy for decision-making on eutrophication management;[263]
- The need to utilise the assimilative capacity of the water resource to accept water containing waste or waste; and
- The associated socio-economic consequences.

Additionally, to the uniform application of WDSs, unique WDSs can also be determined on an *ad hoc* basis, for inclusion in water use authorisations, on a case-by-case basis. This may be necessary in the absence of suitable uniform WDSs, or when there is a justified need for deviation, once they are determined, from the uniform WDSs, such as to enforce stricter or more lenient WDSs in accordance with the Differentiated Approach.[264] Whether enforcing WDSs that were determined on an *ad hoc* basis, or that were derived from any regulation containing uniform WDSs, it is vital that the Receiving Water Quality Objectives Approach[265] must be operationalised, either locally, for the water resource in question or regionally, for a water resource system type. The further the WDSs applicability moves away from a particular water use, the more conservative such WDSs will have to be in order to ensure that effect is given to RDMs (**FIGURE 49**).

3.2.2.2.3 Water use

Section 21 of the NWA (36:1998) collectively defines 11 consumptive, non-consumptive and in-water resource water uses (**TABLE 20**), which may have a profound or more subtle effect on the trophic status of receiving water resources:

TABLE 20: The nutrient-loading potential of water uses that can affect eutrophication.

IN TERMS OF THE NWA (36:1998), WATER USES INCLUDES –		DIRECT[266] RELEVANCE	NOTES
S.21(a)	taking water from a water resource;	×	These water uses can affect the dilution capacity of receiving water resources, which may affect nutrient concentrations and eutrophication.
S.21(b)	storing water;	×	
S.21(c)	impeding or diverting the flow of water in a watercourse[153];	×	

[262] Refer to **POLICY STATEMENT 9**: The application of the Best Practicable Environmental Option.

[263] Refer to **POLICY STATEMENT 2**: The Mitigation Hierarchy for decision-making on eutrophication.

[264] Refer to **POLICY STATEMENT 3**: The Differentiated Approach for the control of excessive nutrient-loading.

[265] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives Approach applied to eutrophication management.

[266] Whereas the purpose of the table is to demonstrate the direct nutrient-loading potential of individual water uses, eutrophication, in turn, also affects down-stream consumptive, *i.e.* S.21(a) and (b), and in-water resource, *i.e.* S.21(k), water uses. Such impacts stem from impaired water quality, excessive primary production and the presence of nuisance biomass that adversely influence the water supplied from dams and water resources; negatively affect abstraction and reticulation infrastructure; and impair recreational activities.

IN TERMS OF THE NWA (36:1998), WATER USES INCLUDES –		DIRECT[266] RELEVANCE	NOTES
S.21(d)	engaging in a stream flow reduction activity;	×	Taking water from water resources for agricultural irrigation purposes is often associated with nutrient-rich return-flows that can enhance eutrophication. The storing of water effects eutrophication since stagnant water promotes algal growth and the recycling of nutrients in deoxygenated bottom waters.
S.21(e)	**engaging in a controlled activity;**	✓	The irrigation of any land with waste or water containing waste, generated through any industrial activity or by a waterwork, has the potential to generate excessive diffuse nutrient pollution of surface and groundwater resources.
S.21(f)	**discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit;**	✓	The discharge of water containing waste, such as sewage or industrial effluent, has the potential to promote excessive nutrient-loading, and to worsen the effects associated with anthropogenic eutrophication.
S.21(g)	**disposing of waste in a manner which may detrimentally impact on a water resource;**	✓	Many waste disposal activities have the potential to generate excessive diffuse nutrient pollution of surface and groundwater resources.
S.21(h)	**disposing in any manner of water which contains waste from, or which has been heated in, any industrial or power generation process;**	✓	Sea-outfalls have the potential to promote excessive nutrient-loading and enhanced anthropogenic eutrophication of coastal marine waters.
S.21(i)	altering the bed, banks, course or characteristics of a watercourse;	×	The alteration of aquatic ecosystems can indirectly affect eutrophication.
S.21(j)	**removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people; and**	✓	Mine water handling, including the discharge of some mine water containing waste to water resources,[267] has the potential to generate excessive point and diffuse nutrient pollution of surface and groundwater resources.
S.21(k)	using water for recreational purposes.	×	Recreational water use does not have a direct relationship with nutrient-loading, other than being detrimentally affected by undue eutrophic conditions. Nevertheless, some recreational activities can also be associated with other water uses, such as the discharge of water containing waste, which contribute to eutrophication. Additionally, some recreational activities, *e.g.,* boating, can have a link to eutrophication symptoms through the active mixing of surface waters that enhances primary productivity in highly utilised surface waters. Another rumoured possibility is the use of phosphate blocks by some fishermen to create feeding sites for better fishing.

TABLE 20 shows that all waste and water containing waste related water uses, potentially, have a direct effect on the nutrient-loading of receiving water resources. A person who uses water – specifically discharges water containing waste, or that disposes of waste, as contemplated in Sections 21(e), (f), (g), (h) and (j)–

- must use the water subject to the conditions specified in the relevant water use authorisation;

[267] The pumping of mine water from underground in order to safely and efficiently continue with mining activities constitutes a S.21(j) water use. However, when the pumped underground mine drainage is treated and/or discharged, the latter action constitutes a S.21(f) water use. Irrigation of mine drainage constitute a S.21(e) water use and the disposal of mine residue constitute a S.21(g) water use. All of these water use examples may promote excessive nutrient-loading, for instance in cases where blasting; or where phosphorus mining is involved.

- is subject to any limitation, restriction or prohibition, in terms of the NWA (36:1998), or any other applicable law;
- must comply with any applicable WDSs or BMPs prescribed under the NWA (36:1998),[268] unless the conditions of the relevant water use authorisation provide otherwise;
- may not waste that water; and
- must return any seepage, runoff or water containing waste, which emanates from that use, to the water resource from which the water was taken, unless the DWS, or a CMA directs otherwise, or the relevant water use authorisation provides otherwise.

3.2.2.2.4 Registration of water use

Any person who uses water in terms of Section 21 of the NWA (36:1998) must register[269] such water use, except-

- any water use listed in Schedule 1 of the NWA (36:1998);
- where registration is not required in terms of a GA; and
- a person who obtains water from a bulk water supplier, a Water Management Institution, or from a communal scheme.

Registration of a water use is not an entitlement to use water and must not be confused with a water use authorisation. A person who no longer wishes to continue with his or her registered water use must apply to the responsible authority for the deregistration of such water use.

Water use registration information is important to eutrophication management, because–

- It serves as official notification of lawful waste and water containing waste related water uses;
- It serves as basis for planning and eutrophication management; and
- It potentially supports the determination of allocated and allocatable water quality.

Verification and Validation (V&V) of waste and water containing waste related water uses must be prioritised to ensure proper registration of such water uses and to determine the extent of lawfulness.

3.2.2.2.5 Lawful water use

Water uses are only permissible, in terms of the NWA (36:1998), if any of the following five entitlements are in place, *i.e.,* if a water use is (**FIGURE 50**)-

- listed in Schedule 1 of the NWA (36:1998);
- generally authorised;
- an Existing Lawful water Use (ELU)[59];
- authorised under an alternative authorisation, if dispensing with the requirement for a licence; or
- licenced.

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268 Refer to Section 26(1)(h) and (i) of the NWA (36:1998).

269 Section 26(1)(c) of the NWA (36:1998) allows for registration of all water uses, including ELU in terms of Section 34(2). Section 29(1)(b)(vi) also states that in the case of a GA, the responsible authority may attach a condition requiring the registration of such water use.

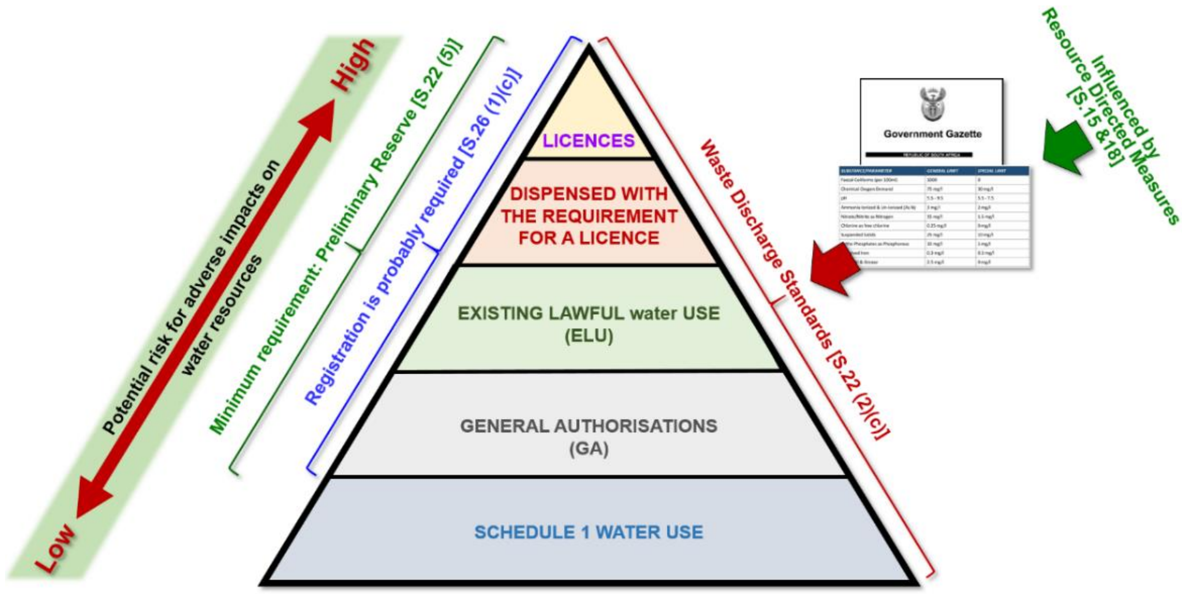

FIGURE 50: Illustration of permissible water use, with references to sections in the NWA (36:1998).

The terms of such entitlements are typically set out in the form of conditions in authorisations or approvals. In the case of the waste and water containing waste related water uses, as highlighted in **TABLE 20**, the conditions set out in the required authorisations or approvals can be utilised to control and manage anthropogenic eutrophication, while at the same time also supporting the needs for socio-economic development. These conditions in the waste and water containing waste related authorisations or approvals often also specify WDSs (**Section 3.2.2.2.2**). A lawful water use, therefore, is a water use that is both permissible, in terms of the NWA (36:1998), and that is compliant with the applicable conditions, including the stipulated WDSs, contained in the water use authorisation or approval in question (**FIGURE 51**).

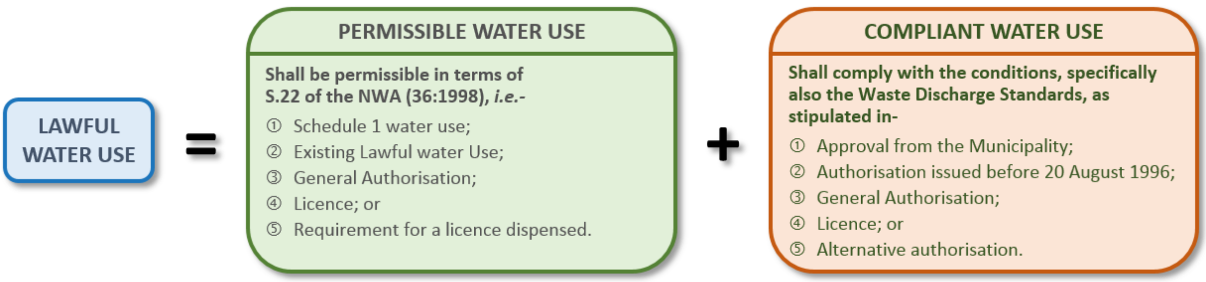

FIGURE 51: Illustration of lawful water use.

The purpose of water use authorisations [adapted from DWAF, 2006a] *inter alia* is to-

- ensure that water is used for the authorised purpose(s) only; and
- enable the DWS to give effect to receiving water resource requirements, such as RQOs, and hence to contribute towards ecologically sustainable development.

Compliance monitoring[27] (**Section 3.3.2.2.1**) and enforcement[50] (**Section 3.4.2.2**) play vital roles in the implementation of WDSs and constitute an essential aspect of eutrophication management.

3.2.2.2.6 Schedule 1 water use

The purpose of Schedule 1 water use is to allow small impact water uses to continue without adding to the administrative burden of the licensing process. Schedule 1 water use entitles a person to use water for reasonable domestic use, and not for commercial purpose. Schedule 1 water use, *inter alia*, includes the discharge of-

- waste or water containing waste; or
- runoff water, including stormwater from any residential, recreational, commercial or industrial site,

into a canal, sea outfall or other conduit controlled by a third party, who are authorised to undertake the purification, treatment and/or disposal of waste or water containing waste, subject to the approval of the third party controlling the canal, sea outfall or other conduit.

Cumulatively, industrial and commercial waste, water containing waste and runoff water have the potential to detrimentally affect the functioning and performance of WwTWs and indirectly influence the extent to which WwTWs can give effect to the Receiving Water Quality Objectives Approach.[270] A better understanding of the water quality character of these Schedule 1 water uses and their influence on municipal wastewater handling is necessary to obtain an improved national understanding of the poor performance records of many municipal WwTWs.

It is foreseen that such an improved national understanding will be beneficial to eutrophication management in South Africa and that additional water quality management intelligence can be generated, such as:

- Information about the character of wastewater and stormwater streams received from commercial and industrial activities, and the effects thereof on municipal WwTWs;
- Information on source directed controls and measures, if any, being applied within the municipal water management environment, including the employment of municipal WDSs, the issuing of conditional approvals and the use of bylaws;
- Compliance information in connection with wastewater and stormwater treatment, if any, by commercial and industrial activities that discharge to municipal sewer network systems; and
- Information on wastewater and stormwater reuse and recycling to promote water conservation and water demand management.

Such additional water quality management intelligence can be utilised to, *inter alia*, inform:

- Research relating to the handling of waste, water containing waste and stormwater generated by the commercial and industrial activities, and by municipalities; and
- Research and development to improve treatment technologies and the application thereof.

3.2.2.2.7 General Authorisations

The purpose of generally authorised water use[271] is to allow relatively low impact water uses to continue and to ease the administrative burden of the licensing process. GAs allow water users to use water without a licence, provided that such water uses are exercised within the conditions set out in the relevant GA. GAs for waste and water containing waste related water uses, *i.e.,* for the Section 21 (e), (f), (g), (h) and (j) water uses, are available. GAs are not necessarily applicable to the whole country and may only be applicable to specific rivers or catchments. GAs are generally reviewed every five years. It is critical that the cumulative effects of generally authorised water uses must not result in the violation of the relevant RDMs and that effect is given to the Receiving Water Quality Objectives Approach.[272]

[270] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives Approach applied to eutrophication management.
[271] Refer to Section 39 of the NWA (36:1998).
[272] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives Approach applied to eutrophication management.

The water use and water resource data and information required by GAs, are vital. For this information to be useful, the provision of relevant water quality and volumetric data must be called for and accepted through a public *e*-portal into (a) database(s) that allow for central interrogation in an information management system, such as a potential IRiS-WMS combination. In this way, a better handle on the cumulative impacts of generally authorised water uses and other water uses, and their collective relationship with RDMs, within the context of the catchment, can be obtained. Once uniform WDSs have been developed, the wastewater limit values in GAs should be substituted with the updated WDSs or references to revised uniform WDSs should be included.

3.2.2.2.8 Existing Lawful water Use (ELU)

Section 32 of NWA (36:1998) identifies water uses that were authorised under legislation, which was in force immediately before the date of commencement of the NWA (36:1998), as Existing Lawful water Use (ELU)[59]. This is subject to the requirement that such water uses took place at any time during the two years prior to the date of commencement of the NWA (36:1998), *viz.* 1 October 1998. The purpose of ELU is to enable existing economic activities, based on the use of water, to continue until such time as compulsory licensing is called for in a particular area.

It is highly likely that ELUs with a potential to cause excessive nutrient-loading, such as those water uses associated with some municipal, industrial or agricultural activities, still exist today. It is also likely that the conditions that were formulated at the time of authorising those water uses, in many cases several years ago, are now out-dated or inadequate. The extent of the compounded nutrient-loading effect on receiving water resources, because of possible out-dated and inadequate ELU authorisation conditions is unknown. In order to ascertain whether this poses an obstacle to giving effect to RDMs, it would be required to commission the necessary Validation and Verification (V&V) studies of all waste and water containing waste related water uses, *i.e.* those highlighted in **TABLE 20**, to update WARMS and to assess the effects of such water uses on RDMs. Effect must be given to the Receiving Water Quality Objectives Approach,[273] and this will allow the DWS to commission (a) compulsory licensing campaign(s), where necessary, to replace all heritage authorisations with for instance licences. In the interim, and prior to the extent of the potential problem, and/or the outcomes of any V&V studies becoming known and the conclusion of any compulsory licensing campaigns, the DWS may wish to improve the regulation of ELUs by means of a regulation published under Section 26 of the NWA (36:1998).[274]

3.2.2.2.9 Water use licensing

Water users must apply for water use licenses for any new water use that is not listed under Schedule 1 of the NWA (36:1998) or that is not covered by a GA. The purpose of licensing is to control water uses that exceed the limits outlined in Schedule 1 of the NWA (36:1998) and those allowed under GAs.

Effective licence administration is of utmost importance to eutrophication management, as is knowledge of waste and water containing waste related water uses that are not permissible under the NWA (36:1998). Licensing, currently, is the single most important instrument in the DWS's arsenal to control and manage waste and water containing waste related water uses with an adverse impact potential. Unlawful water use poses a threat to ecologically sustainable development and the growth potential of the country!

Water use licences give existing or new water users formal authorisation to use water for productive and beneficial purposes, and specify the conditions, including WDSs, under which the water can be used. It is critical that the cumulative effects of all authorised water uses must not result in the violation of relevant RDMs, and effect must be given to the Receiving Water Quality Objectives Approach.[275]

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[273] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives Approach applied to eutrophication management.

[274] Refer to S. 26(1)(a), NWA (36:1998): *"The Minister may make regulations limiting or restricting the purpose, manner or extent of water use."*, and **Annexure F** for other regulations.

[275] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives Approach applied to eutrophication management.

The NWA (36:1998) makes provision for two types of applications for water use licences, *viz.* individual and compulsory applications.

Compulsory licensing will prioritise areas with water shortages (where current or future water demand exceeds water supply) or where pollution is severe (stressed catchments). The compulsory licensing process may be utilised to–

- achieve a fair allocation of water from stressed water resources;
- achieve equity in water allocation through the Water Allocation Reform (WAR) programme;
- promote beneficial use of water in the public interest;
- facilitate water use efficiency; and
- protect water resource quality.

It is important that users register their existing use so that it is considered during compulsory licensing. Catchments that are severely impacted by excessive nutrient-loading, or where licence conditions, specifically the WDSs, do not fully implement the Receiving Water Quality Objectives Approach and where effect is not given to RDMs (*i.e.,* non-compliance to a Reserve or a RQO), must be identified. These areas or river systems can be prioritised for compulsory licensing.

The water use and water resource data and information required by licenses, are vital! For this information to be useful, the provision of relevant water quality and volumetric data must be called for and accepted through a public *e*-portal into database(s) that allow for central interrogation in an information management system, such as a potential IRiS-WMS combination. In this way, a better handle on the cumulative impacts of licenced water uses and other water uses, and their collective relationship with RDMs, within the context of the catchment, can be obtained.

A licence may be issued for a maximum of 40 years[276] and licence conditions may be reviewed at a review period listed in the licence, which may be any period not exceeding five years.[277] The responsible authority may amend any condition of a licence by agreement with the licensee.[278]

3.2.2.2.10 Alternative authorisations

The DWS, or a CMA may dispense with the requirement for a water use licence, if satisfied that the purpose of the NWA (36:1998) will be met by the granting of a licence, permit or other authorisation under any other law. In the interests of cooperative management, the DWS, or a CMA, may promote arrangements with other organs of state to combine authorisation requirements into a single authorisation requirement.

Alternative authorisations, which may have a bearing on eutrophication management, include the regulation of land use activities and the control of development activities through regulations, EMPRs for mining, EIAs for listed activities, atmospheric emission licences, waste management licences, coastal waters discharge permits, prohibitions of certain activities, in line with the NFEPAs, setting of product or technical production standards, and setting of performance standards. Synergy between alternative authorisations, including the examples listed above must be explored, in the interest of management cooperation[279] and efficient eutrophication management.

[276] Refer to Section 28(1)(e), NWA (36:1998).

[277] Refer to Section 28(1)(f), NWA (36:1998).

[278] Refer to Section 52(4), NWA (36:1998).

[279] Refer to **POLICY STATEMENT 19:** Cooperative eutrophication management.

3.2.2.2.11 Diffuse pollution sources

In comparison to point sources of pollution, diffuse sources of pollution and their impacts on human and ecosystem health largely remain under-reported and under-regulated. This is because diffuse pollution sources are challenging to monitor and to regulate, due to [OECD, 2017]–

- their high variability, spatially and temporally, making attribution of such sources of pollution complex;
- the high transaction costs associated with dealing with large numbers of heterogeneous polluters (*e.g.,* agriculture, formal and informal settlements, industry, etc.); and
- because diffuse source pollution control may require co-operation and agreement within catchments, and across sub-national jurisdictions and even with different co-basin states.

It is necessary, and more effective, to utilise combinations of the different management instruments for environmental compliance,[280] *i.e.,* the command-and-control, economic, self-regulatory and societal participation instruments, to improve pollution control, and to manage diffuse nutrient-loading of water resources and ultimately anthropogenic eutrophication. Some instruments that may potentially be employed to manage anthropogenic eutrophication from a diffuse origin are listed in **TABLE 21**. These instruments must be investigated, further developed, and rolled out for eutrophication management, as part of a diffuse source or non-point source (NPS)[95] strategy, that are supported by appropriate BMPs and BPGs.

[280] Refer to **POLICY STATEMENT 1**: Application of management instruments for environmental compliance in eutrophication management.

TABLE 21: Management instruments to address excessive diffuse nutrient-loading of water resources.

Command and control[26] management instruments:	**Societal participation[24] management instruments:**
▶ The use of WDSs to control the discharge of collected diffuse polluted return-flow water, *e.g.,* irrigation return-flows and stormwater; ▶ The use of WDSs to control modelled diffuse water quality outputs; ▶ Conditional water use authorisations to control the discharge of collected diffuse polluted return-flow water, *e.g.* irrigation return-flows and stormwater; ▶ Mandatory BMPs,[281] including the introduction and maintenance of buffer areas; ▶ BPGs to promote eutrophication management efficacy; ▶ Mandatory diffuse source pollution management plans, *e.g.,* irrigation management plans, etc.; and ▶ Load allocations to diffuse nutrient contributors.	▶ Information and awareness campaigns; ▶ Farm advisory and extension services for improved farming techniques (to minimise negative impacts on water quality/ eutrophication and to protect agricultural resources); ▶ *"Management-by-shame"* as a tool, is sometimes employed by Catchment Management Forums, which enjoy diverse representation of forum members with many different interest, views and objectives, that require balancing; ▶ The establishment of task teams within Catchment Management Forums have proved to be effective in, proactively, resolving many technical challenges; ▶ Best environmental practices (or good management practices); and ▶ Eco-labelling – products that meet certain environmental standards can be marketed and sold at a premium and/or subsidised.
Economic[45] management instruments:	**Self-regulatory[133] management instruments:**
▶ Pollution taxes (on inputs), *e.g.,* additional tax on herbicides and pesticides *; ▶ Tax abatements; subsidies or transfers to incentivise good farming practices; ▶ WDCS (on outputs); ▶ Replace synthetic fertilisers with organic fertilisers, thereby promoting recycling and reuse of waste; ▶ Government capital funding to upgrade and maintain wastewater sludge infrastructure and waste disposal; and ▶ Payment for ecological infrastructure services.	▶ Contracts/ bonds (*e.g.,* land retirement contracts); ▶ Voluntary standards and management systems (*e.g.,* ISO 14001); and ▶ Voluntary certification schemes (*e.g.,* Global G.A.P.), linked to independent audits. Good audit results can be incentivised through tax rebates, subsidies or similar transfers.

Note: * May require a legislative amendment.[282]

The fact that the control and management of diffuse sources of pollution is broader than only the management of eutrophication, necessitates the establishment of a Diffuse Source Strategy for South Africa that addresses the full spectrum of diffuse pollution challenges. Such a strategy may include the identification of P and N vulnerable zones to protect surface and groundwater resources in particular areas, and to enforce stricter or special source directed measures and controls. Within these zones, for instance, specific or special fertiliser, manure, crop and livestock farming practices could be made mandatory. Legislative amendments may be required and need to be investigated, as part of the development of a Diffuse Source Strategy for South Africa.[283]

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[281] Refer to Refer to S. 26(1)(i), NWA (36:1998): *"The Minister may make regulations prescribing the outcome or effect which must be achieved through **management practices** for the treatment of waste, or any class of waste, before it is discharged or deposited into or allowed to enter a water resource"*, and **Annexure F** for other regulations.

[282] Refer to **Annexure H** for a list of all recommended legislative amendments.

[283] Refer to **Annexure H** for a list of all recommended legislative amendments.

3.2.2.2.12 Differentiated water use management based on risk

To use the limited government human and financial resources judiciously, and to achieve the greatest impact, a targeted risk-based approach must be adopted to control and manage water use. Under this approach, the potential significance of the impact of water pollution will inform the level of response or intervention from the state. Thus, areas of particular sensitivity will receive heightened attention, as will activities from which the pollution potential is of a particularly hazardous nature and areas where pollution is already extremely high. Such a targeted risk-based approach should–

- be used for the categorisation of water polluters, based on risk,[284] to strengthen differentiated control and management in support of ecologically sustainable development;
- be used to revise the administrative fees of water use authorisation applications to better reflect risk levels and administrative burden;
- inform the water use authorisation process; and
- inform financial provisioning, potentially, to be extended beyond mining to other high risk water users to address *post facto* remedial actions that may be required.

Continual improvement in the processes, to control and manage water uses, will be sought in order to ensure ecologically sustainable development, and to fast-track adaptive eutrophication management responses.[285] Noting that the conditions of regulation provide the conduit for the implementation of policy and strategy on the ground, it will be critical that these conditions also acknowledge catchment requirements. This will mean that these conditions may have to be revisited, from time to time, in support of adaptive eutrophication management requirements [DWS, 2017b, p. 48].

3.2.2.3 Incentive-based regulation

"Show me the incentive and I will show you the outcome!" Author: Charlie Munger

3.2.2.3.1 Waste Discharge Charge System (WDCS)

Raw water pricing, in most cases, are undervalued and any waste discharge pricing will need to be commensurate with the contemporary water pricing strategy. The Waste Discharge Charge System (WDCS) is being developed to promote waste reduction and water conservation. It forms part of the Pricing Strategy, established under the NWA (36:1998). The WDCS is based on the polluter-pays[113] principle and aims to–

- promote the efficient use of water resources and ecologically sustainable development;
- promote the internalisation of potentially externalised environmental costs;
- create financial incentives, rather than being punitive in nature, to promote the prevention, avoidance and reduction of water pollution and the recycling and reuse of waste and water containing waste (in accordance with the Mitigation Hierarchy[286]), and to use water resources in an optimal manner; and
- recover costs associated with the mitigation of resource quality impacts caused by waste and water containing waste related water uses.

Differential rates for discharges can be employed by the WDCS to address discharges that contribute to excessive nutrient-loading, taking into account–

- the characteristics of the waste discharged;
- the load and concentration of any substance being discharged;

[284] An amendment to the NWA (36:1998) is required to allow for the categorisation of polluting industries, based on risk. Refer to **Annexure H** for a list of all recommended legislative amendments.

[285] Refer to **Section 3.4.2.3.2, Part 3**: Continuous management improvement – closing the loop!

[286] Refer to **POLICY STATEMENT 2**: The Mitigation Hierarchy for decision-making on eutrophication.

- the nature and extent of the impact on a water resource caused by the waste discharged or disposed;
- the extent of the permitted deviation, if any, from prescribed WDSs or management practices; and
- the required extent and nature of monitoring the water use.

The WDCS must be implemented in catchments or sub-catchments, as may be appropriate, irrespective of whether the relevant Water Resource Class(es) (and RQOs/ Reserves) is/ are being met or not, as per the waste mitigation hierarchy requirements of Section 2(4) of NEMA (107:1998).[287]

The WDCS must be piloted and implemented to reduce anthropogenic eutrophication.[288]

3.2.2.3.2 Administrative penalties

A system of effective administrative penalties for water pollution offences,[289] extends enforcement to complement criminal prosecution and to fine offenders. Such a system will incentivize polluters[290] to reduce their pollution. A system of effective administrative penalties for water pollution offences must be investigated and potentially implemented. Such an approach is supported by international best practice and will allow environmental compliance officers to issue administrative penalties on the spot. This will require an amendment to the NWA (36:1998).[291]

3.2.2.3.3 Certification Schemes

Non-economic incentive based regulatory approaches, specifically the utilisation of certification schemes, have gained significant momentum in South Africa [DWS, 2014], and currently include the–

- Blue Drop Certification Programme for drinking water quality management regulation;
- No Drop Certification Programme for water use efficiency and water loss management; and
- Green Drop Certification Programme for wastewater quality management regulation.

The Green Drop process measures and compares the results of the performance of water service authorities and their providers via a standardised scorecard, and subsequently rewards (or penalises) the municipality upon evidence of their excellence (or failures) according to the minimum standards or requirements that has been defined. Awareness of this performance is obtained by pressure from customers, the media, political classes and Non-Governmental Organisations (NGOs). The Programme revolves around the identification of mediocre performing municipalities, which consequently correct identified shortcomings, as well as the introduction of competitiveness amongst the municipalities and using benchmarking in a market where competition is difficult to implement. The Green Drop System (GDS) must be strengthened, expanded and implemented, on a sustained basis,[292] in the interest of improving the unacceptable trophic conditions that prevail and emerge in many receiving water resources.

3.2.2.3.4 Water Polluter Register

A Water Polluter Register (or Water User Register), extends reporting to beyond municipalities and to incentivize polluters to reduce their pollution must be investigated and potentially implemented. In the

287 Refer to **POLICY STATEMENT 2**: The Mitigation Hierarchy for decision-making on eutrophication.

288 For the Waste Discharge Levy to be introduced, an amendment to the NWA (36:1998) is required to give the Minister permission to promulgate a Money Bill. Refer to **Annexure H** for a list of all recommended legislative amendments.

289 Refer to **Section 3.4.2.2.1, Part 3**: Administrative penalties.

290 Refer to **POLICY STATEMENT 7**: Incentive-based regulation.

291 Refer to **Annexure H** for a list of all recommended legislative amendments.

292 The Green Drop Certification Programme has been relaunched by the Department of Water and Sanitation with a full Green Drop audit to be conducted in 2021/22.

Water Polluter Register, parties that are meeting BMP standards will be recognised, as will non-compliance by polluting parties. This will require an amendment to the NWA (36:1998).[293]

3.2.2.3.5 Eco-labelling

Eco-labelling can be considered as an extension of conventional marketing practices – a profit-driven response by industry to the commercial pressures of green consumer-consciousness. OECD, 1991 interprets the goals of eco-labelling as follows:

- Improving the sales or image of a labelled product;
- Raising the awareness of consumers;
- Making accurate information publicly available;
- Directing manufacturers to account for the environmental impact of their products; and
- Protecting the environment.

The merits of adopting an eco-labelling scheme for problem nutrients must be investigated and potentially implemented, acknowledging the ambitions of eutrophication management policy.[294]

This will require an amendment to the NWA (36:1998).[295]

For more on this topic, see **CASE STUDY 2**.

CASE STUDY 2: The *"Do"* stage – Eco-labelling as a means to incentivise responsible behaviour.

The United States uses a labelling system, comprised of *"Eco-labels"* and *"Green Stickers"*, for consumer products. *"Ecolabels"* are voluntary, but *"Green Stickers"* are mandated by law. For example, in North America major appliances and automobiles use Energy Star, which is a form of sustainability measurement directed at consumers. It is intended to make it easy to take environmental concerns into account when shopping. Some labels quantify pollution or energy consumption by way of index scores or units of measurement, while others assert compliance with a set of practices or minimum requirements for sustainability, or reduction of harm to the environment. Many eco-labels are focused on minimising the negative ecological impacts of production or resource extraction in a given sector or commodity through a set of good practices that are captured in a sustainability standard. Through a verification process, usually referred to as *"certification"*, a farm, forest, fishery, or mine can show that it complies with a standard and earn the right to sell its products as certified.

The European Union has also developed legislation for eco-labelling and have created their own eco-labels for consumer products. Label trust is an issue for consumers because some manufacturers and manufacturing associations have set up *"rubber stamp"* labels to greenwash their products with fake eco-labels. High trust levels can be created when eco-labels apply for governmental recognition as formal certification marks [Ecolabel Index, 2021].

3.2.3 *Spatial scale of implementation*

The operational strategies in the *"do"* stage of the eutrophication management framework focus on Source Directed Management, addressing the sources of impacts at a source specific scale through source directed measures and controls. These source directed measures and controls are mostly established and enforced by relevant authorities, but the private sector, through self-regulation and voluntary initiatives, and civil society, through management participation and often acting as *"watchdogs"*, also play important roles.

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[293] Refer to **Annexure H** for a list of all recommended legislative amendments.

[294] Refer to **POLICY STATEMENT 6**: A life cycle view on nutrient-loading.

[295] Refer to **Annexure H** for a list of all recommended legislative amendments.

3.2.4 Temporal scale of implementation

The development and implementation of best management practice measures, appropriate to South Africa, are generally time consuming. An adequate portfolio of best management practice measures could, therefore, be some time away and in its absence existing measures and controls must continue to be employed. These measures and controls relate primarily to emission standards and conditional authorisations to avoid, prevent and minimise adverse water pollution effects of land and water use.[296]

The operational strategies, being part of the *"do"* stage in the eutrophication management framework, can be executed on an *ad hoc* basis or regularly, depending on the purpose. **TABLE 22** gives a summary of potential actions, in the *"do"* stage, which must be considered, to improve the trophic status of water resources:

TABLE 22: Operational actions to strengthen the "do" stage of the eutrophication management framework.

	SHORT TERM
1	Deal comprehensively with phosphorus loads in wastewater from WwTWs and render these in line with the assimilable capacity of receiving water resources;
2	Promote the reduction, recycling and re-use of excessive nutrient load containing waste and/or wastewater, in accordance with relevant geographical water quality management strategies and thematic plans;
3	Gazette uniform mandatory national WDSs, specifically revising all eutrophication-related standards, in support of water use authorisations;
4	Address shortcomings with respect to the authorisation conditions of some ELUs that cause, or may potentially cause, excessive nutrient-loading and anthropogenic eutrophication;
5	Develop and implement a protocol to differentiate between water users in terms of risk. The differentiated control and management of sources of excessive nutrient-loading will enable the prioritisation of action and resources;
6	Develop and implement a protocol for an integrated licencing processes to streamline authorisations, including CMA engagement. Efficient authorisation is vital to effective eutrophication control and management;
7	Finalise the WDCS strategy for implementation nationally, including waste discharge charges for nutrient-loading;
8	Establish financial incentives to promote water-reuse and recycling, including the reuse of municipal wastewater, when the water budget allows for it;
9	Develop and/or implement (an) incentive-based programme(s) to benefit eutrophication management, *e.g.,* revitalisation of the Green Drop System (GDS);
10	Validate and verify (V&V) registered water use with a direct water quality impact;
11	Develop and publish a National Pollution Register, which, amongst others, shows compliance to nutrient standards;
12	Achieve and ensure compliance to the requirements of all water use authorisations, specifically including water users that contribute, or may potentially contribute, towards anthropogenic eutrophication;
13	Undertake targeted compulsory licensing/ revision of water use authorisations to ensure compliance with statutory RDMs in key river systems/ WMAs, as necessary;
14	Promote cleaner production and technologies, specifically to combat anthropogenic eutrophication;
15	Eliminate hazardous substances and identify priority substances (including a priority list of unacceptable chemical compounds/ constituents);
16	Investigate and establish stormwater quality measures and controls;
17	Investigate and establish measures and controls for diffuse pollution;

[296] Refer to **POLICY STATEMENT 2:** The Mitigation Hierarchy for decision-making on eutrophication.

SHORT TERM	
18	Develop BPGs for pollution avoidance and prevention, minimisation, remediation and offsetting; and
19	Develop sectoral standards of best management practices and continuous improvement.
LONGER TERM	
20	Develop and implement (a) management system(s) to support an integrated licensing approach;
21	Develop and implement sectoral off-setting policies for water quality and wetlands, based on the Overall Policy on Environmental Offsetting in South Africa [DEFF, 2018]; and
22	Develop a publicly accessible register of all offsets to facilitate compliance monitoring.

3.3 The *"check"* stage

The *"check"* stage, in the eutrophication management framework, must–

- support transboundary and international monitoring campaigns;
- monitor compliance of land and water use activities to any applicable regulatory requirements that support the limiting of anthropogenic eutrophication;
- generate national and regional intelligence on nutrient-loading and the trophic status of water resources;
- evaluate the implementation and effectiveness of management interventions, which aims to limit nutrient-loading and anthropogenic eutrophication; and
- establish suitable information management systems to support and improve data handling and the generation of useful eutrophication-related management information.

The *"check"* stage, in the eutrophication management framework, focuses on four linked operational strategies; these being depicted in **FIGURE 52** as (1) *"International and transboundary status and trends monitoring and reporting"*; (2) *"Domestic status and trends monitoring and reporting"*; (3) *"Although the monitoring tools discussed* in **TABLE 27** help to get a better understanding of related conditions that are either associated with eutrophication or that will help to improve eutrophication management efforts, a monitoring tool that applies to nutrient enrichment specifically has not yet been developed.

Management performance monitoring and reporting*"*; and (4) *"Data acquisition and information management"*.

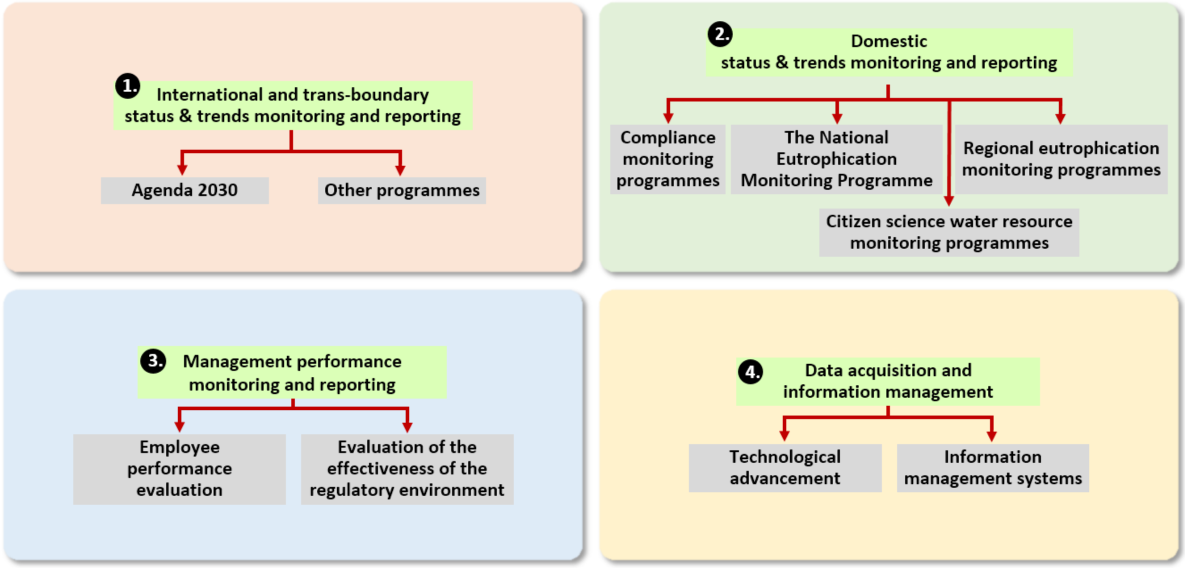

FIGURE 52: Conceptual outline of the *"check"* stage in the eutrophication management framework.

The four operational strategies, and their purpose and composition, are narrated in **TABLE 23**:

TABLE 23: The operational strategies, in the "check" stage of the eutrophication management framework, and their composition.

OPERATIONAL STRATEGIES AND PURPOSE		KEY COMPONENT(S)
1. International and transboundary status and trends monitoring and reporting	*To support transboundary and international eutrophication management related monitoring programmes.*	Agenda 2030 and potential similar future programmes; and
		Other international and transboundary eutrophication-related monitoring programmes.
2. Domestic status and trends monitoring and reporting	*To monitor land and water use compliance to eutrophication management related regulatory requirements, and to track the national and regional trophic statuses of water resources.*	Compliance monitoring programmes;
		The National Eutrophication Monitoring Programme;
		Regional eutrophication monitoring programmes; and
		Citizen science water resource monitoring.
3. Management performance monitoring and reporting	*To track the implementation and effectiveness of eutrophication management measures.*	Employee performance evaluation; and
		Evaluation of the effectiveness of the regulatory environment.
4. Data acquisition and information management	*To ensure access to eutrophication-related data and information.*	Technological advancement; and
		Information management systems.

3.3.1 Authority

It is vital that the causes of anthropogenic eutrophication and the effects of excessive nutrient-loading on water resources, and on social and economic development, must be monitored by relevant authorities[297] in order to gauge the effectiveness of regulatory approaches, and to identify potential management

[297] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

shortcomings and potential improvement opportunities. Competencies (sectors), which are relevant here, include: agriculture; the environment; health; monitoring and evaluation; and water and sanitation. These competencies are linked to responsible authorities in Chapter 5 of Part 3 that addresses ***"Governance"***, and that gives additional resolution to the assigning of roles and responsibilities in a eutrophication management context.

3.3.2 Prescribed approaches

"You can't manage what you don't measure!" Author: Peter Drucker

3.3.2.1 International and transboundary status and trends monitoring and reporting

3.3.2.1.1 Agenda 2030 and potential similar future programmes

Agenda 2030 calls for the regular monitoring of a series of indicators, and for the reporting on a three yearly basis to the United Nations (UN) on six key and two supporting targets on the sustainability of *"clean water and sanitation"* in countries. The *"clean water and sanitation"* key targets cover "drinking water"; *"sanitation and hygiene"*; *"wastewater and water quality"*; *"water use and scarcity"*; *"integrated water resource management"*; and *"water related ecosystems"*, and the supporting targets cover *"international cooperation"*; and *"local participation"*.

FIGURE 53 shows the target and indicators for wastewater and water quality. SDG Target Indicator 6.3.2 constitutes the ultimate indicator to demonstrate and track the fitness-for-use of countries' water resources, specifically also including requirements to report on the nitrate-nitrite (NO_3-NO_2) and orthophosphate (PO_4^{3-}) status and trends observed in receiving water resources. Agenda 2030 also calls for the regular compliance monitoring and reporting to the UN on several point and diffuse sources (through the additional indicators) of water pollution that potentially contribute towards anthropogenic eutrophication. These monitoring and reporting approaches should be internalised and expanded to improve South Africa's domestic monitoring programmes,[298] in support of effective eutrophication planning, regulation and management.

[298] Refer to **Section 3.3.2.2, Part 3:** Domestic status and trends monitoring and reporting.

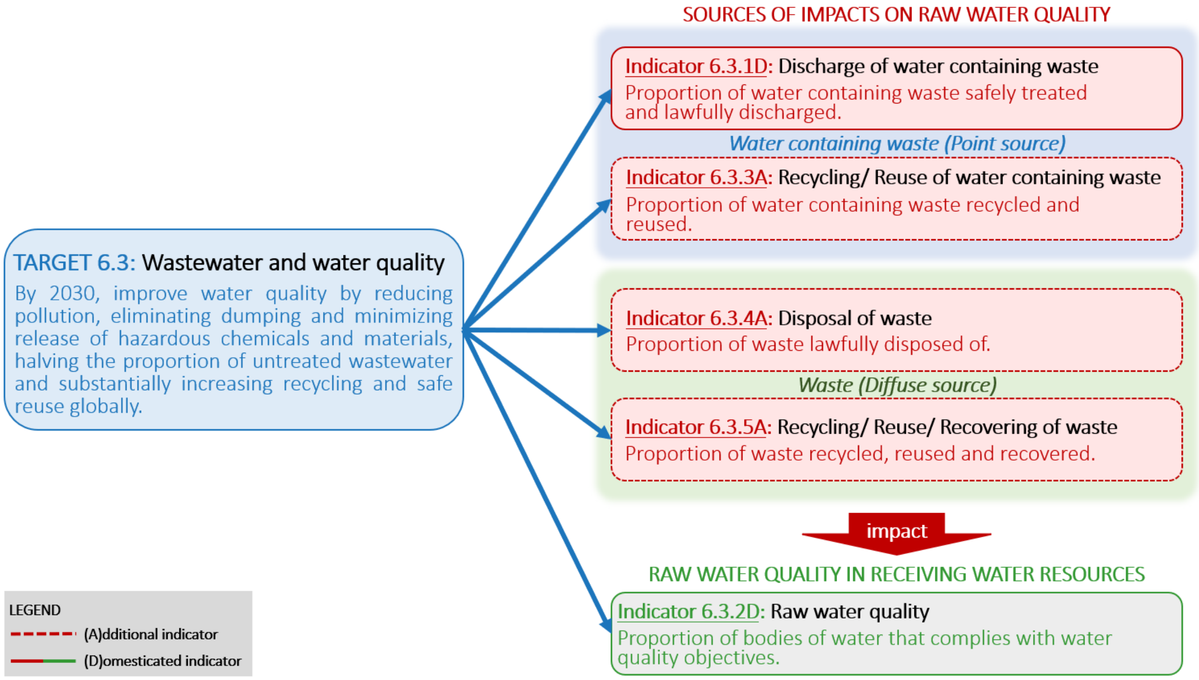

FIGURE 53: Relationship between SDG Target 6.3 and its indicators [Van Wyk, et al., 2020].

Reporting to the UN on these aspects must not be viewed as additional requirements but should be integrated into the day-to-day agenda to manage eutrophication and to generate suitable water quality intelligence to promote effective water quality management and water security.[299] Similar to the SDGs constituting a country programme, eutrophication management must also become part of the country agenda aiming to support and facilitate ecologically sustainable development.

3.3.2.1.2 Other international and transboundary eutrophication-related monitoring programmes

International and transboundary status and trend monitoring programmes focus on shared drainage regions[40], and drainage regions or ecological infrastructure of international significance. These programmes mostly aim to address matters of global relevance, or to deal with matters of common interest to promote healthy relations, and sustainable water resource use and development through collaboration and water diplomacy.

The GEMS/Water Programme is a good example of such an international monitoring programme. The GEMS/Water Programme was established in 1978 as an interagency programme under the auspices of the United Nations to collect world-wide water quality data for assessments of status and trends in global inland water quality. In 2003, South Africa joined in the GEMS/Water Programme – being an active participant ever since [Van Niekerk, 2004]. **FIGURE 54** provides an international profile, which emanated from this programme, of total phosphorus loading of major lakes and shows how significant modes of anthropogenic eutrophication differ between industrialised and agricultural economies, and developed and developing countries. Today, the GEMS/Water Programme is operating in more than 124 countries around the world and is providing water quality data to a central database known as GEMStat.

[299] Refer to **TABLE 9**: SDG 6 targets and indicators, with direct relevance to eutrophication management.

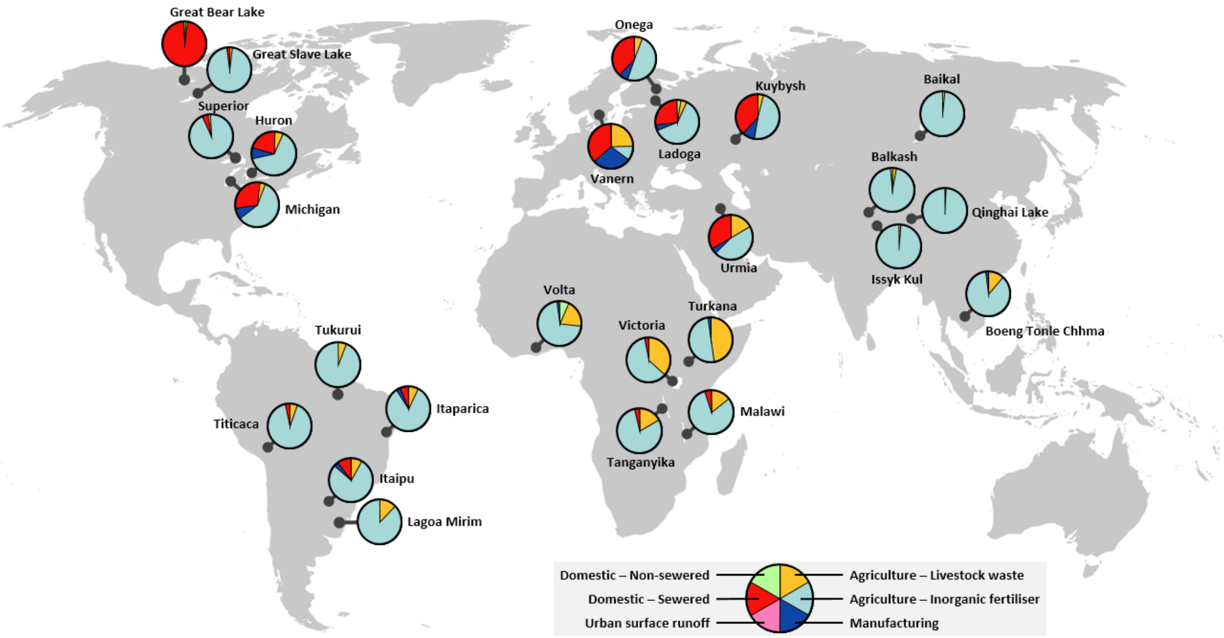

FIGURE 54: Sources of anthropogenic total phosphorus loadings to major lakes, shown as average percentage contributions to annual loading between 2008 and 2010 [UNEP, 2016].

Another example of international important collaboration relates to the Ramsar Convention on Wetlands, which South Africa co-signed with more than 170 other countries on the management of identified significant wetlands. On 21 December 1975, South Africa became a signatory to the Ramsar Convention,[300] and consequently needs to regularly report on the status of the 27 South African sites currently designated as Ramsar Wetlands. Of the two South African sites currently listed on the Montreux Record of Ramsar Wetlands – *i.e.,* sites *"where changes in ecological character have occurred, are occurring, or are likely to occur as a result of development, pollution or other anthropogenic interference"* – at least one, namely the Blesbokspruit Wetland, is being affected by excessive nutrient (and hydraulic) overloading [Ramsar, 2021].

Additionally, South Africa shares three river basins with sovereign neighbouring countries in the Southern African Development Community (SADC) region (**TABLE 24**):

[300] Refer to **POLICY STATEMENT 8**: Nature-based solutions.

TABLE 24: Shared river basins and watercourse institutions.

SHARED BASIN	CO-BASIN STATES	SHARED WATERCOURSE INSTITUTIONS	AGREEMENT
Inco-Maputo	▶ Eswatini; ▶ Mozambique; and ▶ South Africa.	Tripartite Permanent Technical Committee between the Republic of Mozambique, the Republic of South Africa and the Kingdom of Ezwatini *(TPTC)*	Tripartite Interim Agreement between the Republic of Mozambique and the Republic of South Africa and the Kingdom of Eswatini for co-operation on the protection and sustainable utilisation of the water resources of the Incomati and Maputo Watercourses (2002)
Orange Senqu	▶ Botswana; ▶ Namibia; ▶ Lesotho; and ▶ South Africa.	Orange-Senqu River Commission *(ORASECOM)*	Revised Agreement between the governments of the Republic of Botswana, the Kingdom of Lesotho, the Republic of Namibia, and the Republic of South Africa on the establishment of the Orange-Senqu Watercourse Commission (2019)
Limpopo	▶ Botswana; ▶ Mozambique; ▶ South Africa; and ▶ Zimbabwe.	Limpopo Watercourse Commission *(LIMCOM)*	Agreement between the Republic of Botswana, the Republic of Mozambique, the Republic of South Africa and the Republic of Zimbabwe on the establishment of the Limpopo Watercourse Commission (2003)

Of the three shared watercourse institutions listed above, ORASECOM, in 2000, was the first to be established and to be fully operational. ORASECOM, in 2010, commissioned the first of its joint basin surveys – to be repeated five yearly. The most recent Survey revealed that exacerbated eutrophic conditions, pertaining to the Orange-Vaal River System, are mostly associated with urban centres, including also downstream of the city of Maseru, Lesotho [Ross-Gillespie, et al., 2015], underscoring the importance for transboundary collaboration [301] on aspects relating to eutrophication monitoring, reporting and management. The remaining two watercourse institutions have not yet commissioned joint water resource quality surveys.

3.3.2.2 Domestic status and trends monitoring and reporting

Domestic compliance and resource quality status and trends monitoring and reporting, specifically with respect to eutrophication management, should remain focused, cost-effective and sustainable, and must ensure that [DWAF, 2006b, p. 53]–

- monitoring programmes have well-defined objectives;
- the monitoring designs provide the maximum amount of demonstrably useful information at minimum cost;
- data assessments and reports support informed decision-making;
- no duplication of effort occurs at any stage of implementation; and
- appropriate partnerships should be created with stakeholders who will share costs and benefits.

Acknowledging the limitations that may exist with respect to financial, and other resources, it is essential that suitable and quality verified resource quality data and information must be collected on an uninterrupted basis to support high confidence water resource planning, informed decision-making and efficient eutrophication management.

[301] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

Water quality, quantity and aquatic ecosystems are interconnected and the following eutrophication-related data and information (**TABLE 25**), depending on whether causes or effects are being monitored, are regarded as useful and necessary:

TABLE 25: Eutrophication-related variables.

MONITORING TYPE	PARAMETER
	Drivers/ stressors
Physico-chemical[109] monitoring	Typically, inorganic variables, but also physical attributes, organic and inorganic toxicants, including temperature, pH, turbidity, Secchi disk depth, DO, BOD, COD and nutrients.
Microbial monitoring	Typically, faecal microorganisms, such as *Escherichia coli*, which are also often associated with poorly operated WwTWs. Microbial processes happen within the cycle of aquatic life and are relevant in the assessment of eutrophication and nutrient budgets.
Volumetric monitoring	Typically stream flow or effluent discharge volumes, necessary to determine loading* and dam volumes for assimilative capacity.
	Responses
Eutrophication monitoring	Use trophic status indices (*e.g.,* Total P and Chl-α) as indication of the trophic conditions of surface water resources.
Biomonitoring	Use bio-indicators, such as diatoms, and other invertebrates, and fish, to assess aquatic ecosystem health. Silicon (Si) is an indicator of freshwater dispersion and potential for diatom blooms.
Toxicity monitoring	Such as neuro- and hepato-toxins, released from some algal species, which can kill animals and pose a threat to human health. Note: The presence of specific algal species will contribute to knowing which toxins to measure for.

Note: * *"Total load"* is a useful indicator of eutrophication impacts on water resources. A *"high concentration"* indicates an immediate problem, but if only present in a small flow volume, the overall impact will be limited and/or local. The use of grab sampling with relatively low sampling frequencies for the calculation of nutrient-loading would fail to provide accurate load estimates, and generally under-estimate the total loads being moved through a river system.

The rating of water resources according to a Trophic State Index (TSI) for the classification of waterbodies according to the amount of biological productivity they sustain, can, on a regular basis, be utilised, together with nutrient-loading and other eutrophication-related information, to inform eutrophication management and to gauge management performance. Consideration must also be given to include TSI information in the Water Resource Class(es) (and RQOs/ Reserves) to firmly link resource requirements with SDCs, and regional water quality monitoring programmes.

Unnecessary duplication of monitoring must be avoided, and monitoring efforts must be harmonised and integrated, where possible and desirable – especially across the various spheres of government – with other existing monitoring programmes. Monitoring programmes must be appropriately resourced and strengthened to support the heightened efforts to clamp down on excessive nutrient-loading and anthropogenic eutrophication. Eutrophication-related information requirements can vary considerably and depend on, among other factors, the spatial scale of interest (**FIGURE 55**).

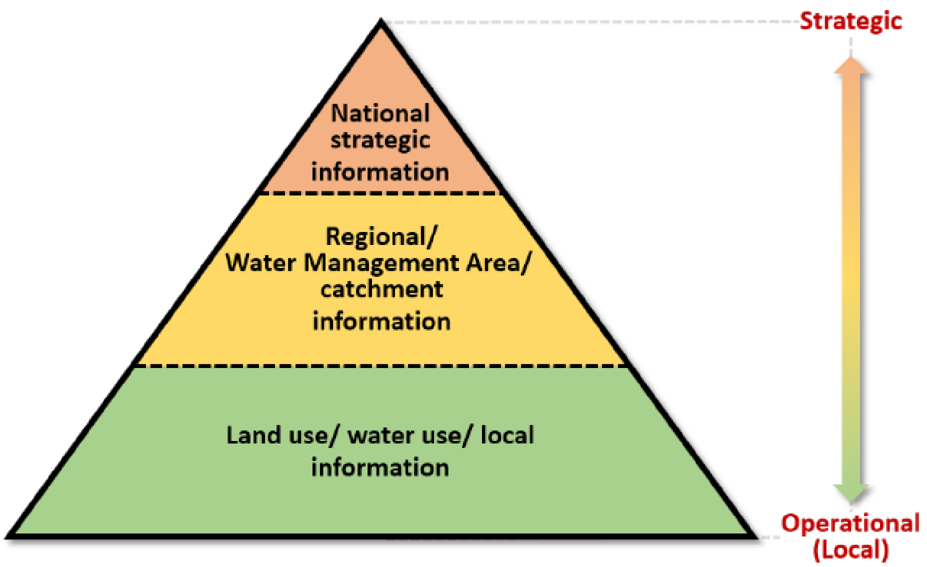

FIGURE 55: Hierarchy of domestic information requirements for eutrophication management [adapted from DWAF, 2006e, p.9].

The following programmes for domestic compliance and resource quality status and trends monitoring and reporting must be maintained:

- Compliance monitoring;
- National eutrophication monitoring; and
- Regional eutrophication monitoring.

These programmes are presented next:

3.3.2.2.1 Compliance monitoring programmes

The **purpose of compliance monitoring** is to measure, assess and report, on a regular basis, the degree to which–

- water users, such as municipalities, comply with the requirements of certification schemes, such as the Green Drop System, which are applied as part of non-economic incentive-based regulation;[302]
- individual land and water uses comply with relevant regulatory requirements, such as BMPs[303] or the WDSs[304] stipulated in water use authorisations, or conditions stipulated in alternative authorisations,[305] or the requirements of voluntary certification schemes, such as Global G.A.P. for *"good agricultural practice"*; and
- individual land and water uses impact on the local or regional water resource quality, including through diffuse impacts.[306]

The primary users and use of this type of information, and their responsibilities are summarised in **TABLE 26**:

[302] Refer to **POLICY STATEMENT 7**: Incentive-based regulation.
[303] Refer to **Section 3.2.2.1, Part 3**: Best management practice.
[304] Refer to **Section 3.2.2.2.2, Part 3**: Waste Discharge Standards (WDSs).
[305] Refer to **Section 3.2.2.2.10, Part 3**: Alternative authorisations.
[306] Refer to **Section 3.2.2.2.11, Part 3:** Diffuse pollution sources.

TABLE 26: Compliance monitoring information – key users, use and management responsibilities.

KEY USER	USE OF INFORMATION	MANAGEMENT RESPONSIBILITY
Land or water user	The information will indicate to land and water users the extent to which adequate measures have been taken to limit and control likely impacts on the quality of local water resources. Non-compliance can indicate the need for pro-active corrective actions to be taken by such land and water users.	The primary responsibility for regulatory compliance resides with the individuals or organisations whose water or land use is being monitored. Water use licence conditions typically stipulate upstream and downstream monitoring, and monitoring of any discharge of water containing waste.
Relevant authority	The information will indicate whether land and water users are complying with regulatory conditions, such as those contained in water use licenses. Non-compliance may lead to several possible actions in order to ensure regulatory compliance.	Relevant authorities have the responsibility to audit the results by performing their own sampling and analysis.

Catchment compliance monitoring (**FIGURE 56**) typically includes-

- monitoring upstream and downstream of point and diffuse sources of impact (*"Level 3"*);
- monitoring of discharges of water containing waste for compliance with authorisation conditions purposes (*"Level 4"*); and
- the monitoring of resource quality variables relevant to the impact or as specified in the applicable authorisation.

In the interim, until revised, the General and Special Standards for the purification of Wastewater or Effluent can be used to assess most effluent data [GN R.991, 1984]. The South African Water Quality Guidelines, in the absence of suitable RDMs, can be used to assess water resources [DWAF, 1996]. Where RQOs and supporting RWQOs/ WQPLs are determined, these should be sensibly back-calculated to WDSs to assess effluent data.[307]

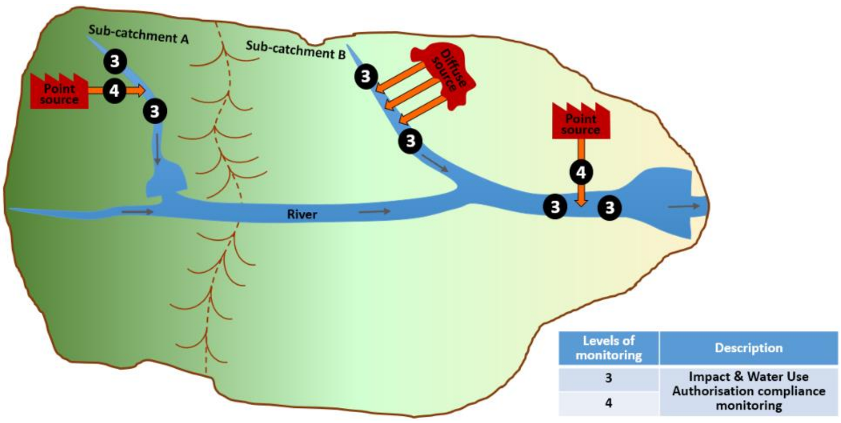

FIGURE 56: Illustration of compliance monitoring levels [DWAF, 2006e].

Municipalities receive Green Drop status when they achieve scores of 90% or higher, against the stringent Green Drop compliance requirements. Green Drop scores are given per individual wastewater system within the municipal area for the following:

- Capacity management;
- Environmental management;

[307] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives Approach applied to eutrophication management.

- Financial management;
- Technical management;
- Effluent and sludge quality compliance;
- Green Drop bonuses;
- Green Drop penalties;
- Disqualifiers.

Expanding non-economic incentive-based regulation,[308] such as Green Drop Certification, to other non-municipality water users must be considered in order to expand the compliance monitoring programmes,[309] reporting and transparency.[310]

Data will be converted into information and regularly (quarterly or longer) published in compliance monitoring reports that explicitly also address eutrophication management related compliance.

3.3.2.2.2 The National Eutrophication Monitoring Programme

A **purpose of national eutrophication status and trends monitoring** is to measure, assess and report, on a regular basis, the status, and spatial and temporal trends relating to excessive nutrient-loading and anthropogenic eutrophication in South African water resources, in a manner that will support strategic eutrophication management decisions nationally, in the context of fitness-for-use and aquatic ecosystem integrity.[311]

National water resource quality monitoring (**FIGURE 57**) typically includes–

- monitoring at sites that are chosen at a low spatial resolution, but at strategically important sites from a national point of view (*"Level N"*);
- the monitoring of resource quality variables that may relate to any international responsibilities; the Reserve; and any in-water resource water quality objectives, such as RQOs.

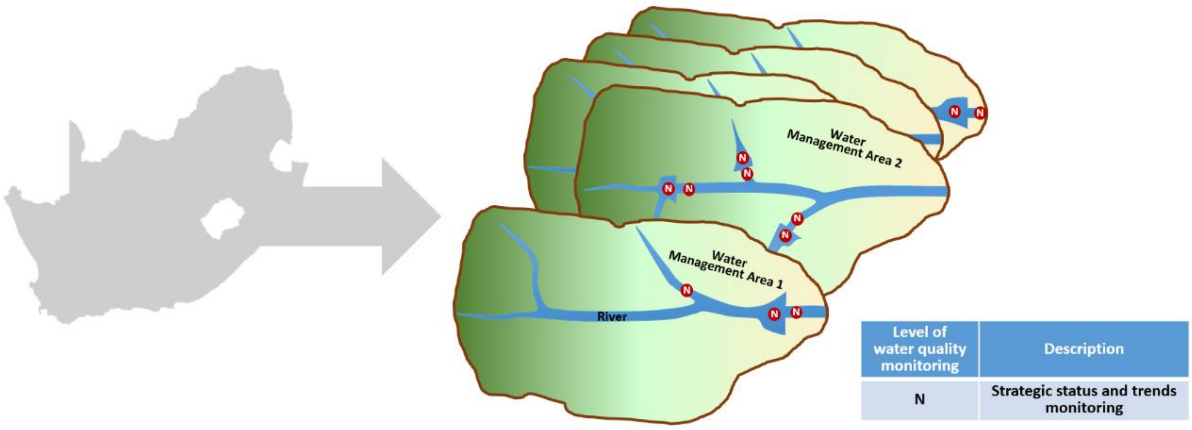

FIGURE 57: Illustration of national (N) status and trend monitoring [Adapted from DWAF 2006e].

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[308] Refer to **POLICY STATEMENT 7**: Incentive-based regulation.

[309] Refer to **Section 3.2.2.3.4, Part 3**: Water Polluter Register.

[310] Refer to **POLICY STATEMENT 17**: Transparency.

[311] The National Aquatic Ecosystem Health Monitoring Programme (NAEHMP), which includes *inter alia* the River Eco-status Monitoring Programme (REMP), formerly the River Health Programme (RHP), the National Estuaries Monitoring Programme (NEsMP) and the National Wetland Monitoring Programme (NWMP) provides information on aspects of the quality of aquatic ecosystems, and can be considered in combination with the National Eutrophication Monitoring Programme (NEMP) to better understand the impacts of nutrient-loading on aquatic ecosystems.

The following strategic responsibilities, which motivate the need for national eutrophication monitoring, are acknowledged:

- The need to monitor the overall national effectiveness of eutrophication management related policies and strategies,[312] which themselves are usually regionally focussed;
- The need to honour international obligations and the participation in sanctioned global and transboundary initiatives;
- Keeping abreast of international trends in emerging problems; and
- The creation of monitoring capacity, especially in the current interim transitional phase as CMAs become operational, upon which further region-specific capacity creation can be based.

The DWS is the custodian of the National Eutrophication Monitoring Programme (NEMP).[313] The NEMP, *inter alia*, aims to establish [DWAF, 2002]–

- the trophic status, with respect to key reservoirs;
- an early warning system, with respect to wastewater treatment;
- an early warning system, with respect to algal blooms;
- an early warning system, with respect to the presence of invasive macrophytes;
- an early warning system, with respect to potential longer-term impacts; and
- strategic nutrient balances.

Data will be converted into information and regularly (annually or longer) published as eutrophication management related status and trends reports, such as Status of the Water Resources Reports and Water Quality Planning-level Review Reports.

3.3.2.2.3 Regional eutrophication monitoring programmes

The **purpose of regional eutrophication monitoring** is to measure, assess and report, on a regular basis, the status, and spatial and temporal trends relating to excessive nutrient-loading and anthropogenic eutrophication in major water resources, in a manner that will support strategic eutrophication management decisions in Water Management Areas (WMAs), in the context of fitness-for-use and aquatic ecosystem integrity.

Whereas the *“Level N”* monitoring sites form part of the national eutrophication monitoring network, the *“Levels 1 to 4”* monitoring sites refer to regional water resource quality monitoring [DWS, 2017e] that is geared towards providing regional eutrophication management-related intelligence that is necessary for integrated water quality management at the scale of the WMA and its sub-catchments (**FIGURE 58**):

- **Impact and Water Use Authorisation compliance monitoring:** This typically entails upstream and downstream monitoring of sources of impact, including diffuse impacts (*"Level 3"*), and the monitoring of effluent discharges to monitor compliance with authorisation conditions relating to *"end-of-pipe"* WDSs (*"Level 4"*);
- **Strategic status and trends monitoring:** This can include major watercourses (*"Level 1"*) and key tributaries of those watercourses (*"Level 2"*). This kind of monitoring is conceptually aligned with the objectives of the existing national water quality monitoring programme. However, on a regional and local scale this should ultimately be aligned with relevant in-water resource water quality objectives[74] and Nutrient Load Objectives (NLOs); and
- **Reserve monitoring:** This entails determining whether the water quality component of the Reserve is satisfied or not, and may require monitoring at *"Level 3", "Level 2" or "Level 1"*.

[312] Refer to **Section 3.3.2.3.2, Part 3**: Evaluation of the effectiveness of the regulatory environment.
[313] More information on the NEMP is supplied in **Annexure G**.

Whereas the DWS takes primary responsibility for all national water quality and related monitoring programmes, as well as for regional water quality monitoring programmes in the absence of CMAs, through proto-CMAs, the delegation of the responsibility for the implementation and the associated data management of regional monitoring programmes to CMAs will occur once CMAs are established, fully operational and adequately capacitated. Where CMAs are established, regional eutrophication monitoring should be embedded in the relevant Catchment Management Strategies.

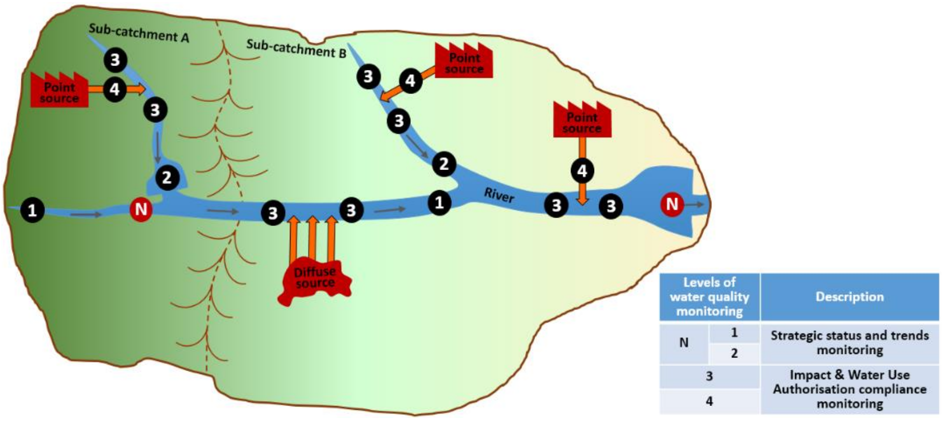

FIGURE 58: Illustration of compliance, and national and regional monitoring [Adapted from DWAF 2006e].

The number of sites that exist as part of the National Eutrophication Monitoring Programme should be augmented to provide a monitoring resolution that is more suitable for the management of eutrophication in the WMA and sub-catchments (**FIGURE 59**). Compatible flow measurement at these monitoring site locations is necessary to assess compliance to NLOs.[314]

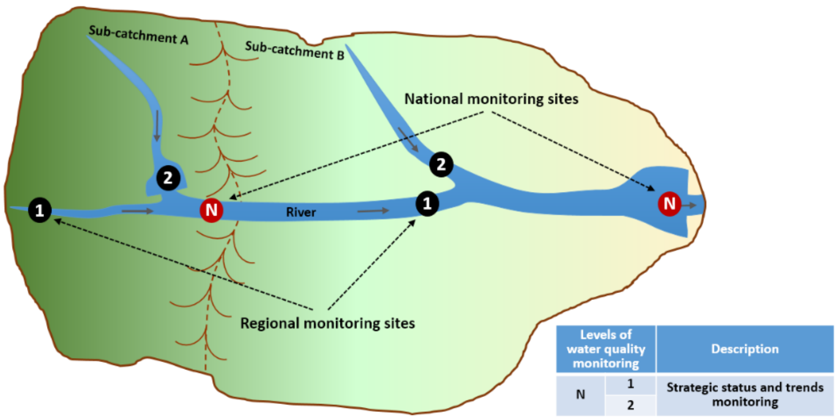

FIGURE 59: Augmenting national monitoring to obtain a regional profile [DWAF, 2006e].

Data will be converted into information and regularly (monthly or longer) published as eutrophication management related status and trends reports, such as WMA Water Quality Status Reports.

[314] Refer to **Section 3.1.2.3.2, Part 3**: Determination of Waste Load Objectives.

3.3.2.2.4 Citizen science water resource monitoring

"Citizen Science" is scientific research conducted in whole, or in part, by amateur or nonprofessional scientists, or retired water resources professionals, engineers, and interested professionals, often by crowdsourcing and crowdfunding. Citizen science is formally defined as *"the systematic collection and analysis of data; development of technology; testing of natural phenomena; and the dissemination of these activities by researchers on primarily a vocational basis"*. Citizen science is sometimes also called *"public participation in scientific research"* [Graham & Taylor, 2018].

As a concept, *"citizen science"* is growing in popularity and interest in many scientific and social circles. Various water resource monitoring tools exist (**TABLE 27**), which can also contribute to catchment eutrophication management, particularly with respect to the ability of citizens to improve their understanding both from the bottom-up (citizens' understanding of catchment eutrophication issues and societies impacts on the trophic status of water resources), but also from the top-down (authorities' understanding where there are major eutrophication issues and problems).

TABLE 27: The Water Research Commission citizen science toolkit [Graham & Taylor, 2018].

AVAILABLE TOOLS	SUITABILITY TO MONITOR ASPECTS OF EUTROPHICATION
1. Aquatic biomonitoring tool (miniSASS)	A low technology, scientifically reliable and inexpensive participatory tool which can be used by anyone to monitor the health of a river.
2. The Riparian Health Audit;	The Riparian Health Audit is based on the scientific *"Index for Habitat Integrity"* (IHI) method. Users assess a riparian reach by determining its natural condition, identifying the extent of impacts in the reach and then rating the principal impacts, if any, that alter the ecological health of the riparian reach being assessed.
3. The Water Clarity Tube;	Suspended solids affect water clarity and comprises several types of material, including soil particles, planktonic[111] organisms and organic matter.
4. The Transparent Velocity Head Rod;	A very simple tool to measure the velocity and discharge of a stream or river.
5. The Wetland assessment tool;	A method for assessing wetland ecological condition based on land-cover type.
6. The Estuary tool;	Assists with the monitoring and management of an estuary on a routine and structured basis.
7. The Spring tool;	The Spring Health Index tool leads the citizen scientists through several steps to determine the current ecological condition of springs, starting with determining the location and type of such springs, investigating the surrounding land cover and use and the geomorphology of the area. The ecological condition is calculated as the percentage of change that has occurred to the spring system, compared to its natural (original) condition, giving a description of the current conditions of the spring.
8. Rain Gauge;	Capturing of rainfall data.
9. Weather monitoring tools; and	Capturing wind speed and direction, as well as temperature.

Although the monitoring tools discussed in **TABLE 27** help to get a better understanding of related conditions that are either associated with eutrophication or that will help to improve eutrophication management efforts, a monitoring tool that applies to nutrient enrichment specifically has not yet been developed.

3.3.2.3 Management performance monitoring and reporting

Achieving sound monitoring and reporting of the causes and effects indicators of eutrophication, as outlined above, is by far the most pressing need, whether it be in support of international and transboundary monitoring programmes; for compliance monitoring purposes; for national or regional water resource quality monitoring purposes; or for citizen science water resource monitoring purposes.

This view, however, needs to be expanded to a more ambitious perspectives on monitoring to better understand the eutrophication causal chain. The paradigm introduced next, *i.e. "Employee performance evaluation"* and *"Evaluation of the effectiveness of the regulatory environment"*, will assist in understanding, interpreting and presenting the results obtained through resource quality monitoring.

3.3.2.3.1 Employee performance evaluation

Employee performance in most organisations is managed, regularly evaluated and, in most instances, annually reported through the application of performance management and development systems, which are generally linked to such organisations' business plans, or the like.

This is also the case in the civil service. To achieve individual excellence and achievement, employee performance management, in government [DPSA, 2007], strives to–

- establish a performance and a learning culture in the Public Service;
- improve service delivery;
- ensure that all jobholders know and understand what is expected of them;
- promote interaction on performance between jobholders and their supervisors;
- identify, manage and promote jobholders' development needs;
- evaluate performance fairly and objectively;
- recognise categories of performance that are fully effective and better; and
- manage categories of performance that are not fully effective and lower.

The inclusion of tangible performance criteria in the performance agreements of relevant employees, especially in the case of relevant civil servants and officials working in local government, which relate to any responsibilities in connection with the management of causes or effects of excessive nutrient-loading, must be considered for annual evaluation. Such eutrophication management related performance criteria may relate to any, or any variation, of the following:

- Internal audit outcomes linked to the environmental compliance performance of industry;
- The Green Drop score(s) of one or more WwTWs;
- Proportion of water containing waste recycled or reused in a particular geographical area or by a particular industry;
- Proportion of effluent discharges in a particular geographical area that is appropriately authorised;
- Proportion of water containing waste in a particular geographical area, or of an industry, that is lawfully discharged;
- Proportion of waste lawfully disposed;
- Proportion of waste recycled, reused or recovered; and
- Proportion of bodies of water, including groundwater, in a particular geographical area that complies with specified in-water resource water quality objectives.

3.3.2.3.2 Evaluation of the effectiveness of the regulatory environment

This type of broader evaluation applies to (1) the general ***"policy, strategy and law environment"***; as well as (2) specific ***"interventions"***, which collectively influence regulatory effectiveness.

Policy drives **strategy** and often also **legislation**. Evidence is critical in the entire policy cycle – from diagnosis of a problem or opportunity – to monitoring and evaluation – and back to policy development or review [Presidency, 2020]. Evidence based monitoring separates facts from opinions. Performance information on programmes that are designed to implement policy should determine whether to continue with that policy, as an option, or to establish ways in which it should be modified.[315]

Government's Socio-Economic Impact Assessment System (SEIAS) can be used to assess and monitor the social and economic impacts of eutrophication management related policies, strategy, legislation, and other general regulatory arrangements. The SEIAS is aimed at improving the regulatory environment, by *inter alia* analysing risks and proposing ways to mitigate them. Additionally, the Driver-Pressure-State-Impact-Response (DPSIR) framework ,[316] as undertaken and reported under **Section 1.2** in Part 1, can be utilised to evaluate social and economic activities (the *"driving forces"*) that exert *"pressures"* on ecosystems and that change the *"state"* of those ecosystems, which, again, may lead to various *"impacts"*, resulting in *"responses"* from society that ultimately aim to mitigate those *"impacts"* by directly addressing the *"driving forces"*, *"pressures"*, the *"state"*, or *"impacts" inter* alia through improvements to the regulatory environment.

Effectiveness monitoring and evaluation [Presidency, 2020, p. 15], with respect to the *"policy, strategy and law environment"*, has the following requirements:

- **Relevance:** The evaluation should be cognisant of the purpose of the policy and strategy, namely, to suitably address the causes and effects of excessive nutrient-loading and to realise the stated Eutrophication Management Goal;[317]
- **Significance:** The evaluation must make a difference and improve the current trophic status being experienced in problem water resources;
- **Originality:** The evaluation must generate new information that was not available before the evaluation was undertaken;
- **Legitimacy:** The evaluation must enjoy the support of relevant stakeholders;
- **Reliability:** The data-collection process must be stable and exist across time and space to ensure data accuracy;
- **Validity:** The findings and conclusions of the evaluation must have effective causal linkages with the descriptive, factual component of the evaluation. Evaluation techniques and indicators must clearly and directly measure the performance intended to be measured;
- **Objectivity:** The evaluation should be undertaken in an impartial and unbiased way, and any value or normative judgments should be minimised and openly declared; and
- **Timeliness:** The evaluation findings should be based on recent performance and should be available in time to influence future intervention decisions.

The suitability and roll-out (see Chapter 2 of Part 4) of the Eutrophication Management Strategy for South Africa must be monitored and regularly evaluated. The ultimate indicator is the trophic status and resource quality of receiving water resources. Continuous deteriorating trophic conditions and resource quality points to a failure of strategy and/or to a failure of strategy roll-out. Strategy implementation over time must be benchmarked and evaluated against the requirements of the Strategy into Practice Report and against the ambitions and requirements of the Eutrophication Management Strategy for South Africa.

Specific interventions, to address issues of anthropogenic eutrophication in catchments and water resources, are most efficiently implemented when executed, based on appropriate water resource planning.[318] Coherent implementation of these measures requires roll-out in accordance with the geographical water quality management strategies and thematic plans[319] applicable to those catchments and water resources. In this instance, utilising strategy steering committees presents an effective

[315] Refer to **Section 3.4.2.3.1, Part 3:** Policy and strategy revision, where necessary.
[316] The River Health Programme, amongst others, uses the DPSIR framework.
[317] Refer to **Chapter 2 in Part 2**:Visionary perspective.
[318] Refer to **POLICY STATEMENT 14**: Water resource assessment and planning to inform decision-making.
[319] Refer to **Section 3.1.2.4.6, Part 3**: Establishment of geographical water quality management strategies and thematic plans.

mechanism to oversee, coordinate and to maintain strategy and plan implementation. The objectives of such committees, which can be utilised to implement and maintain interventions to address catchment-specific eutrophication challenges, include the following:

- To identify and highlight water quality issues of concern, including eutrophication, in relation to the mandate and responsibility of each of the committee member organisations;
- To facilitate coordination between the various components within the DWS (Head directorates and Regional Offices); CMAs; and other relevant authorities, with the aim of giving effect to the relevant geographical strategies and thematic plans;
- To promote coordination and integration of water quality management related actions throughout all relevant sub catchments;
- To ensure the implementation, and where appropriate the updating, of the relevant geographical strategies and thematic plans; and
- To ensure accurate and efficient feedback about the implementation of the abovementioned actions to the strategy steering committee and/or any other relevant structures.

3.3.2.4 Data acquisition and information management

3.3.2.4.1 Technological advancement

The world is embracing the fourth industrial revolution, in which mobile communications, social media and sensors are blurring the boundaries between people, the internet and the physical world. Ways to work smarter should be explored! Careful planning often converts short-term cost into long-term benefit. Improvements to information management should be carefully considered with the objective to improve management efforts and to ultimately improve South Africa's raw water quality.

The DWS pioneered the use of satellite data for monitoring eutrophication in the 1980s [Howman, et al., 1989; Howman & Kempster, 1986]. The types of sensors available, the cost of satellite images and the lack of computer processing power led to the closure of the project. During the 2010s, developments in space technology and satellite remote sensing have made the monitoring of eutrophication in standing waterbodies from space, a reality. The first development was a retrospective determination of the status and trends of chlorophyll-α,[320] cyanobacterial[31] blooms and cyanobacterial surface scum in South African dams from 2002 until 2012, using sophisticated algorithms in conjunction with data from the Medium Resolution Imaging Spectrometer (MERIS) on the European Space Agency's Envisat [Matthews, 2014; Matthews & Bernard, 2015]. These results are available on the DWS Water Management System (WMS) database. Later, similar techniques using the newer sensors on the European Space Agency's Sentinel satellites in combination with cellular telephone technology, culminated in the CyanoLakes App, developed in partnership with the WRC [Matthews & Kravitz, 2022]. This approach is the first of its kind to provide quantitative water quality information for South Africa's waterbodies from a time series of Earth observation data. The app is available on Android and Apple devices worldwide and is now used internationally for any waterbody within certain size limits. Satellite remote sensing requires calibration against in-situ monitoring, so the continuation of the National Eutrophication Monitoring Programme is integral to its success.

Alternative cost-effective technologies, as a means of more effective eutrophication management, must be considered and promoted.[321] Such initiatives may include technologies like the use of drones (although current legislation is not conducive to the easy use of drones) to monitor water channels and large reservoirs, smart sensors to monitor discharges from WwTWs and, additionally, to schedule maintenance[81].

[320] Chlorophyll-α (Chl-α) is a proxy for eutrophication.

[321] **POLICY STATEMENT 16**: Promotion of eutrophication-related research.

Data and information availability must keep pace with the Fourth Industrial Revolution. Employing Application Programming Interface (API) technology would allow app developers to access data more easily to show eutrophication management related information in near real time in apps, equivalent to weather apps.

For more on the utilisation of remote sensing technology to monitor eutrophication, see **CASE STUDY 3**.

CASE STUDY 3: The *"Check"* stage – The utilisation of remote sensing technology to monitor eutrophication.

The study has demonstrated both the power and efficiency of satellite remote sensing to monitor eutrophication on a sub-continental (national) scale. The project indicated that satellite remote sensing estimates compare closely with in-situ data from the National Eutrophication Monitoring Programme. It showed that it can be used to supplement monitoring programmes to fill information gaps and to provide new insights into the occurrence and seasonality of cyanobacterial blooms and surface scum. It was recommended that satellite remote sensing be integrated into the National Eutrophication Monitoring Programme to take advantage of historical data and those data that will become available from future satellite missions, in particular from the Sentinel-3 mission.

The condition of 50 of South Africa's largest waterbodies, regarding trophic status (Chl-α) and the occurrence of cyanobacterial blooms and surface scums, was assessed. It was shown that most waterbodies are heavily impacted by eutrophication and cyanobacterial blooms. As much as 62% of the waterbodies were hypertrophic. Cyanobacterial blooms were recorded in all the waterbodies and cyanobacteria surface scum posing a high health risk occurred in 26 (or 54%) of the 50 waterbodies. An added advantage of the use of the cellular phone applications, is that recreational water users can make sure that they are planning their excursions to a safe environment on a near real time basis. Surface scum events became more common between 2005 and 2011 in four waterbodies. Therefore, eutrophication and cyanobacterial blooms remain issues of critical concern for water security in South Africa and require urgent and sustained management attention **[Matthews & Bernard, 2015]**.

3.3.2.4.2 Information management systems

Primary data capturing can potentially occur in any of at least two conceivable ways, namely:

- The capture of results in the laboratory;
- The capture of laboratory results by the data owner (whether being an authority, or a land or water user) on a centralised database.

In either case, the probability of human error must be minimised. Clear and robust protocols must exist to ensure that the data, once captured on a centralised database, are stored in such a way that would facilitate subsequent efficient access and processing. All data must be stored so they can be made available-

- when a reasonable request for data is received from stakeholders or interested parties. Data held by the state should be provided, at reasonable charge, if necessary, in line with the AIA (2:2000) and the NWA (36:1998);
- preferably online and free of charge, especially to schoolchildren, university students and/or pensioners; and
- to report on eutrophication related matters, as part of formal and regular information dissemination mechanisms, including requirements of water use authorisations for resource quality data.

TABLE 28 lists various corporate information management systems utilised by the DWS:

TABLE 28: Departmental information management systems.

INFORMATION MANAGEMENT SYSTEM	APPLICATION
Electronic Water Use License Application and Authorisation System *(e-WULAAS)*	The online web portal for the submission, processing and authorisation of water use licence applications.
Green Drop System *(GDS)*	The GDS for the evaluation of water service authorities and their providers, via a standardised scorecard, has now been replaced by IRiS.
Hydrological Data System *(HYDSTRA)*	The database containing long time-series hydrological data, such as dam water levels, evaporation, rainfall and streamflow.
Integrated Regulatory information System *(IRiS)*	To capture an organization's engagement in the locally and nationally determined wastewater treatment requirements to ensure that wastewater treatment is up to the set standards.
National Integrated Water Information System *(NWIS)*	To provide information products to the public through web-based dashboards to facilitate efficient analysis and reporting across the water value chain.
Water use Authorisation and Registration Management System *(WARMS)*	The national register of water use to store and produce accurate water use information.
Water Management System *(WMS)*	A suite of water quality monitoring systems to provide information on water resource monitoring and management.

According to the DWS's Data Management Strategy, the four main pillars for efficient and effective data acquisition and management, namely–

- data governance;
- data life cycle management;
- data management systems; and
- alignment between stakeholders in the water and sanitation sectors,

must be enhanced to improve the authoritativeness, availability, accessibility, timeliness and security of data [DWS, 2020].

3.3.3 Spatial scale of implementation

The operational strategies in the *"check"* stage of the eutrophication management framework address the full continuum of geographical scales, ranging from the international and transboundary level, to the national, regional, and land and water use activity specific levels. Additionally, the *"check"* stage also contains strategies that extend monitoring and evaluation to the performance of employees; the effectiveness of the broader policy, strategy and law environment; and, ultimately to the implementation of catchment and water resource specific interventions.

3.3.4 Temporal scale of implementation

The operational strategies, being part of the *"check"* stage in the eutrophication management framework, in most cases, must be attended to on a regular and continuous basis.

TABLE 29 gives a summary of potential actions, in the *"check"* stage, which must be considered, to improve the trophic status of water resources:

TABLE 29: Operational actions to strengthen the *"check"* stage of the eutrophication management framework.

	SHORT TERM
1	Resolve supply chain management challenges to ensure the availability of back-to-back laboratory services to support eutrophication management on a continuous basis. The running of a laboratory supply chain has similarities with pharmacy supply chains, *e.g.,* strict specifications, on-time delivery, unbroken cold-chain, safe disposal of expired reagents, etc.;
2	Undertake routine national eutrophication monitoring, considering the recommendations of the Review of the South African Water Resource Monitoring Network report [DWS, 2016b];
3	Strengthen the NEMP and establish a TSI for rivers and streams.
4	Realign/ establish regional eutrophication monitoring programmes, in cooperation with all relevant role-players, and undertake routine regional eutrophication monitoring;
5	Undertake appropriate flow measurements, as part of the national and regional eutrophication monitoring programmes, to enable nutrient load monitoring and apportionment on a WMA and sub-catchment basis;
6	Consider and, where desirable, develop and implement citizen science eutrophication monitoring programmes, in support of other resource quality monitoring programmes;
7	Consider and, where necessary, introduce and mainstream advanced technology to monitor eutrophication, *e.g.,* remote sensing, drone technology, etc.;
8	Improve the effectiveness and efficiency of the water quality data management system(s) through the implementation of the findings of the Data Management Strategy [DWS, 2020]. Good data management is a prerequisite for effective eutrophication management;
9	Expand IRiS to capture data and information from water users that monitor the disposal of waste/ discharge of water containing waste for compliance monitoring purposes. The availability of suitable data and information will improve the management of eutrophication;
10	Develop and gazette regulations to compel water users to register and upload waste discharge water quality and volumetric data, specifically data and information that will aid eutrophication management, on the Integrated Regulatory Information System (IRiS), or alternative system(s);
11	Generate and compile annual national eutrophication-related compliance monitoring status reports;
12	Generate and compile biennial national eutrophication status reports;
13	Generate and compile annual catchment eutrophication status report(s);
14	In conjunction with regular reporting, implement the provision of near real time and on-demand information so that managers do not have to wait such reports;
15	Learn from the SDG Programme, and expand South Africa's domestic monitoring programmes, in support of effective eutrophication planning, regulation and management, to incorporate the useful concepts from the SDG Programme;
16	Harmonise the systems and approaches being used across sector departments and catchments for resource water quality data and information management;
17	Structures, such as the National Water Quality Management Forum, the Anti-Pollution Task Team and the Water Quality Management Steering Committee, must be utilised as platforms for regular reporting, performance tracking and deliberating;
18	The DWS will be responsible for the national assessment of water quality, and will report annually to Parliament on the state of water quality in the country, including Municipalities' Green Drop performance; and
19	Law review to enforce monitoring within the municipal water value chain, especially monitoring and submission of data by commercial and industrial activities that discharge to municipal sewer network systems.
	LONGER TERM
20	Harmonise the systems and approaches being used across sector departments and catchments for resource water quality, including eutrophication, data and information sharing and management; and

21	Government to ensure the harmonisation of data and information systems pertaining to source control, especially with respect to land use that contribute towards anthropogenic eutrophication.

3.4 The *“act”* stage

Altogether the *“act”* stage, in the eutrophication management framework, must ensure that–

- all remaining sources of excessive nutrient-loading, or residual effects of anthropogenic eutrophication, are appropriately addressed;
- all regulatory and administrative measures are adequately enforced;
- management measures, such as policy and strategy, are improved, where necessary; and
- management improvement is facilitated through a continuous process of learn-by-doing and adapting.

The *“act”* stage, in the eutrophication management framework, focuses on three linked operational strategies; these dealing with (1) *“Retroactive action”*; (2) *“Enforcement”*; and (3) *“Management review”*, as illustrated in **FIGURE 60**.

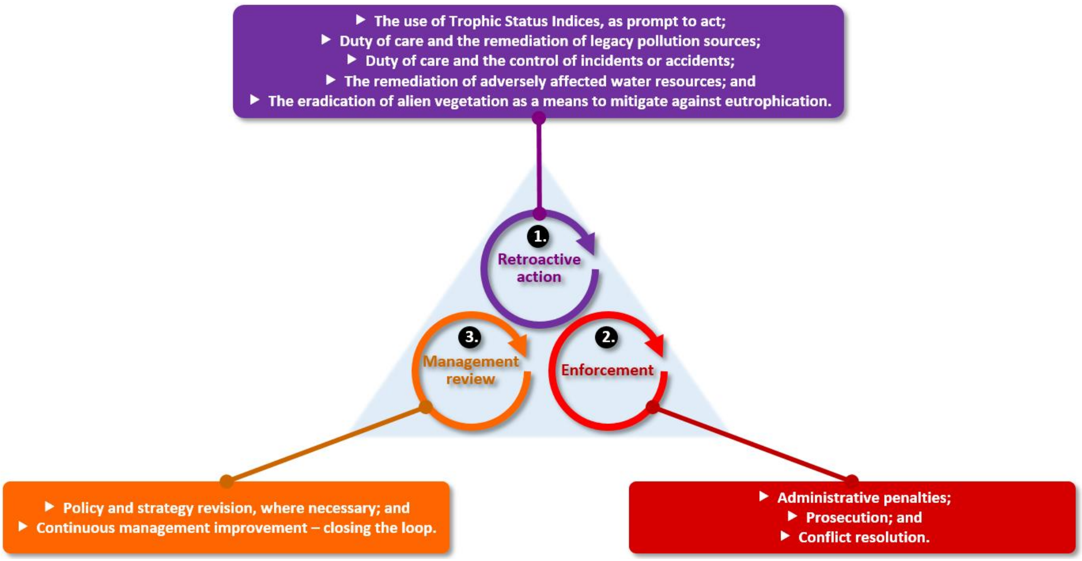

FIGURE 60: Conceptual outline of the *“act”* stage in the eutrophication management framework.

The “*act*” stage, of the eutrophication management framework, comprises three operational strategies. These operational strategies, and their purpose and composition, are narrated in **TABLE 30**:

TABLE 30: The operational strategies, in the “act” stage of the eutrophication management framework, and their composition.

OPERATIONAL STRATEGIES AND PURPOSE		KEY COMPONENT(S)
1. Retroactive action	*To institute retroactive action to address legacy cases of excessive nutrient-loading or residual effects of anthropogenic eutrophication.*	The use of Trophic Status Indices, as prompt to act;
		Duty of care and the remediation of legacy pollution sources;
		Duty of care and the control of incidents or accidents;
		The remediation of adversely affected water resources; and
		The eradication of alien vegetation as a means to mitigate eutrophication.

OPERATIONAL STRATEGIES AND PURPOSE		KEY COMPONENT(S)
2. Enforcement	*To impose administrative and regulatory sanction that is fair and just.*	Administrative penalties;
		Prosecution; and
		Conflict resolution.
3. Management review	*To effect policy and strategy review, where necessary, and to facilitate continuous management improvement.*	Policy and strategy revision, where necessary; and
		Continuous management improvement – closing the loop!

3.4.1 Authority

Data and information generated during the *"check"* stage are vital to appropriately inform and direct all necessary responses to be instituted in the *"act"* stage of the eutrophication management framework. Such responses are focussed on the remaining sources of excessive nutrient-loading or the effects thereof, and the role of regulators[322] to impose relevant policy, strategy and/or law effectively. Competencies (sectors), which are relevant here, include: agriculture; disaster management; the environment; human settlements; mining; and water and sanitation. These competencies are linked to responsible authorities in Chapter 5 of Part 3 that addresses ***"Governance"***, and that gives additional resolution to the assigning of roles and responsibilities in a eutrophication management context.

3.4.2 Prescribed approaches

3.4.2.1 Retroactive action

"Perspective will come in retrospect!" Author: Melody Beattie

3.4.2.1.1 The use of Trophic Status Indices, as prompt to act

Consideration must be given to the development of formal alert levels for problem and other water resources, as part of an early warning system that, amongst others, utilises trophic status assessment information. Such a system should be used to warn water users, in particular recreational water users and vulnerable raw water users, including use for traditional ceremonies and rituals, of potential water quality, health and safety concerns. Potential *"alert levels"* that may be considered, include:

- **A *"Vigilance Level"***: This level can be defined by relatively low nutrient concentrations in raw water. When the *"vigilance level"* is exceeded, affected waterbodies must be sampled more frequently so that potentially rapid changes in cyanobacteria biomass[15] can be detected timeously;
- **An *"Alert Level 1"***: This level can be initiated above a particular cyanobacterial cell count and/or chlorophyll-α concentration detected. This alert level requires an assessment to be made of the total toxin concentration in raw water, in consultation with relevant authorities, for an on-going assessment of the status of the bloom and of the suitability of water for human and animal consumption and use. It may be appropriate, at this time, to issue advisory public notices through the media or other means.
- **An *"Alert Level 2"***: This level can be initiated above tolerable cyanobacterial cell count and/or chlorophyll-α concentrations detected, with the presence of toxins confirmed by

[322] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

chemical or bioassay techniques. This density of cells corresponds to an established toxic bloom with high biomass and possibly localised scums. In this situation, there is a need for effective water treatment and an assessment of treatment performance. Hydro-physical measures to reduce cyanobacteria growth may still be attempted. In extreme situations, tanked safe drinking water should be supplied to consumers. Media releases and contact with consumers should be undertaken via leaflets informing that water may present a danger for human and animal consumption, that boiling of the water is not an option to make the water safe for consumption (as directed in the case of bacterial pollution impacts), but it is still suitable for the purposes of washing, laundry and toilet flushing.

Consideration must be given to the fact that **anthropogenic eutrophication is often also associated with other water pollution concerns**, such as microbial water pollution. In this way, members of the public can be made aware of potentially hazardous conditions, as may be linked to the trophic status of a particular problem water resource [EU & WHO, 2002]. The use of cellular telephone applications can help recreational water users (including use for cultural and/or religious purposes) to plan their excursions to a safe environment on a near real time basis.

3.4.2.1.2 Duty of care and the remediation of legacy pollution sources

"Pollution", according to the NWA (36:1998), is an omission,[323] activity, process,[324] or situation[325] that alters the physical, chemical or biological properties of a water resource. This alteration could happen or be done directly or indirectly. The alteration of the properties of water, further, should make the water resource–

- less fit for any beneficial purpose for which it may reasonably be expected to be used; or
- harmful or potentially harmful to–
  - the welfare, health or safety of human beings;
  - any aquatic or non-aquatic organisms;
  - the resource quality; or
  - property.[326]

To constitute *"water pollution"*, the said alteration of the physical, chemical or biological property need not necessarily make the water resource *"unfit for use"*, or *"harmful"*. It only has to cause the water resource to become *"less fit for use"*, such as in cases of excessive nutrient-loading and occurrences of anthropogenic eutrophication that affect the trophic status trajectory of receiving water resources. Therefore, after the *"pollution"*, it might still be possible to use such water resources, but with precaution.[327]

Additionally, it is also possible that the impact of an activity on its own does not pollute any water resource, while the cumulative point or diffuse impacts of all the activities do. Such activities still pollute the water resource, provided the activity complies with all the regulatory requirements, where causation between the activity and the impact is not too remote. All the persons responsible for these activities in this scenario are, therefore, joint wrongdoers.

As such, there is a duty on–

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[323] Refer to Section 151(1)(i), NWA (36:1998).
[324] Refer to Section 19(1)(a), NWA (36:1998).
[325] Refer to Section 19(1)(b), NWA (36:1998).
[326] Refer to Section 1(1)(xv), NWA (36:1998).
[327] Refer to **Section 3.4.2.1.1, Part 3**: The use of Trophic Status Indices, as prompt to act.

- the owner of land;
- a person in control of land; or
- a person who occupies or uses land;

to take all reasonable measures to *"prevent any pollution"* of water resources from occurring, continuing or recurring, if an activity or process is or was performed or undertaken on land, or any other situation exists on land which causes, has caused or is likely to cause pollution of a water resource. The person who has to undertake the measures is, therefore, not necessarily the person who is or was responsible for the activity, process or situation. The activity or process could even have taken place before the person concerned became the owner of the land or in control of the land or occupied or used the land.

The measures to be taken may include measures to–

- cease, modify or control any act or process causing the pollution;
- contain or prevent the movement of pollutants;
- eliminate any source of the pollution; and
- remedy the effects of the pollution.[328]

If a person who must take measures to prevent or remedy the effects of pollution fails to take them, the Minister may in writing direct that person to commence taking specific measures before a given date, diligently continue with the measures and complete them before a given date.[329] Should a person fail to comply, or comply inadequately, the CMA (or proto-CMA) may take the measures it considers necessary to remedy the situation and, by applying the polluter-pays-principle,[330] recover all costs incurred jointly and severally from the following persons:

- Any person who is or was responsible for, or who directly or indirectly contributed to the pollution or the potential pollution;
- The owner of the land at the time when the pollution or the potential for pollution occurred, or that owner's successor in title;
- The person in control of the land or any person who has a right to use the land at the time when–
  - the activity or the process is or was performed or undertaken; or
  - the situation came about; or
- Any person who negligently failed to prevent–
  - the activity or the process being performed or undertaken; or
  - the situation from coming about.

Additionally, a person who fails to comply with an issued directive is guilty of an offence and is liable, on the first conviction, to a fine or imprisonment for a period not exceeding five years, or to both a fine and such imprisonment and, in the case of a second or subsequent conviction, to a fine or imprisonment for a period not exceeding ten years or to both a fine and such imprisonment.[331] The maximum of the fine depends on the jurisdiction of the court hearing the case.

Most pieces of environmental legislation, today, contains provisions to enforce the environmental duty of care[42] principle and *ex post facto*, or retrospective enforcement through Section 28, NEMA (107:1998) is possible.

[328] Refer to Section 19(2), NWA (36:1998).

[329] Refer to Sections 19(3), NWA (36:1998), read with Section 1(5), NWA (36:1998).

[330] Refer to **POLICY STATEMENT 7**: Incentive-based regulation.

[331] Refer to Section 151(1)(d) and (2), NWA (36:1998). See Section 154, NWA (36:1998) for the acts and omissions by an employee or agent that constitute an offence.

3.4.2.1.3 Duty of care and the control of incidents or accidents

A person responsible for an *"incident"* or *"accident",*[332] in which a substance pollutes; or has the potential to pollute water resources; or has a detrimental effect on water resources, must, as soon as reasonably practicable, after obtaining knowledge of the *"incident"* or *"accident"*, report the *"incident"* or *"accident"* to the DWS; the South African Police Service (SAPS); or the relevant fire department; or the relevant CMA (or proto-CMA).[333] Section 20 of the NWA (36:1998) deals with *"incidents"* and *"accidents"*, such as:

- Accidents involving a tanker transporting a hazardous substance where the substance is spilled;
- Spillage of a hazardous substance at a factory;
- Accident at a factory involving a hazardous substance;
- Spillage from a French drain into a water resource; and
- Overflow of water containing waste from an evaporation dam.

The person concerned must–

- take all reasonable measures to contain and minimise the effects of the *"incident"* or *"accident"*;
- undertake clean-up procedures;
- remedy the effect of the *"incident"*; and
- take measures as the CMA (or proto-CMA) may either verbally (which must be confirmed in writing within 14 days) or in writing direct.[334]

Should the person concerned fail to comply; or inadequately comply with a directive; or it not be possible to give the directive to the responsible person timeously, the CMA (or proto-CMA) may take the measures it considers necessary to–

- contain and minimise the effects of the *"incident"*;
- undertake clean up procedures; and
- remedy the effects of the pollution.[335]

The CMA (or proto-CMA), by applying the polluter-pays-principle,[336] may recover all reasonable costs incurred by taking these steps from the persons responsible.[337]

3.4.2.1.4 The remediation of adversely affected water resources

In cases where water pollution has already caused water resources to become *"less fit for use"*; or *"potentially harmful";* or *"harmful"*, remedial measures must be considered and should be implemented to remedy the water resources in question. The measures must be reasonable, which means the measures to be taken depends on the circumstances of each case. Accelerated eutrophication, which is harmful and difficult to repair, is one of the most pervasive water pollution problems of our time. The remediation of adversely affected water resources constitutes retroactive action, principally to augment and complement any existing and required regulatory and catchment interventions,[338] to address the residual effects or symptoms associated with increasing trophic status trajectories in receiving water resources. As a rule, the

[332] The word *"emergency"*, although present in the explanatory note and in the section heading, does not feature in Section 20, NWA (36:1998). Section 1(4), NWA (36:1998) states that explanatory notes must not be used in the interpretation of the Act. Therefore, the courts have not dealt with the word *"emergency"* in the context of Section 20, NWA (36:1998).

[333] Refer to Section 20(1) to (3), NWA (36:1998).

[334] Refer to Section 20(4) and (5), NWA (36:1998).

[335] Refer to Section 20(6), NWA (36:1998).

[336] Refer to **POLICY STATEMENT 7**: Incentive-based regulation.

[337] Refer to Section 20(7) to (9), NWA (36:1998).

[338] Refer to **Section 3.2, Part 3**: The *"do"* stage.

polluter-pays-principle[339] will be applied to the cleaning-up of legacy pollution cases. Financing and implementing remediation in those cases deemed to be the State's responsibility will continue.

There are three categories of water resource remediation methods in application, namely, ***"physical"***, ***"chemical"***, and ***"biological"*** categories. *"Physical"* and *"chemical"* methods have fast responses to improve water resources in the short term and are more suitable for small-scale interventions. However, these two methods cannot fundamentally solve the eutrophic water phenomenon due to costly and incomplete removal results. Without sound wastewater treatment and suitable regulatory interventions, the *"chemical"* method easily produces secondary pollution and residues, and is usually used for emergency situations. The *"biological"* method is more cost-effective and sustainable but needs a long-term period [Zhang, et al., 2020]. A combination of these three water resource remedial techniques can be used, to develop short and long-term remedial management strategies, that control current cyanobacterial blooms and to restore ecosystems.

Attempts at *"chemical"* eutrophication remedial action mainly involves agents, such as copper sulphate ($CuSO_4$), herbicides, and algaecide. $CuSO_4$ treatment is widely used as a global and empirical method to remove or control phytoplankton[110] blooms [Zhang, et al., 2020]. *"Physical"* methods are often referred to as engineering solutions. These methods refer to physical eutrophication remedial action, such as flushing and dilution (which replenishes waterbodies with water from extraneous sources or other waterbodies, that are lower in nutrient levels), deep (hypolimnetic) or shallow (epilimnetic) aeration (the release of phosphorus from the sediment can be efficiently prevented through the use of mechanical stirring, circulation pump systems or so called Solar-Bee technology, air injection, oxygen injection, or other measures), sediment dredging (removal of the internal sedimentary phosphorus loading sources), and many more [Zhang, et al., 2020]. *"Biological"* eutrophication remedial action is the preferred measure for ecosystem re-establishment of natural cycles, which is considered the ultimate target of eutrophication control. However, the effects of *"biological"* eutrophication remedial action can be enhanced in combination with the *"physical"* and/or *"chemical"* eutrophication remedial methods.

Ecological remediation is using *"biological"* and other supporting methods, to adjust the stability of waterbodies and buffer the speed of nutrient circulation by restoring and rebuilding relatively complex ecosystems, ultimately, re-establishing a healthy ecosystem. *"Biological"* methods could reinforce the interaction between microorganisms and aquatic organisms and the self-purification ability of waters when treating aquatic pollution. Bioremediation uses specific microorganisms, aquatic plants, and aquatic animals to degrade, absorb, and transform nutrients [Zhang, et al., 2020]. *"Biological"* manipulation techniques target food-chain functioning and involve the use or harvesting of non-desirable organisms to eventually control algal growth or other components of the food chain that may cause eutrophication-related problems [Mitchell, et al., 2016]. The main aim is to control certain key species at critical points in the food web, *e.g.,* fish species that prey on zooplankton[162] to an extent that may alter the normal functioning of the ecosystem [Van Ginkel, 2011].

Best Management Practices (BMPs), with guidelines for water resource remediation, should be considered and, if merited, developed. These practices should then be included, as part of a remediation strategy to address impaired, degraded and contaminated water resources.[340] The roll-out of all requisite resource remediation actions must be done in a catchment context, through appropriate catchment assessment, the establishment and implementation of geographical water quality management strategies, and thematic plans.[341]

[339] Refer to **POLICY STATEMENT 7**: Incentive-based regulation.

[340] Refer to **Section 2.3, Part 3**: Remediation Directed Management.

[341] Refer to **Section 3.1.2.4.6, Part 3:** Establishment of geographical water quality management strategies and thematic plans**.**

3.4.2.1.5 The eradication of alien vegetation as a means to mitigate eutrophication

Invasive alien plants constitute a significant environmental problem in South Africa's terrestrial and freshwater ecosystems. Alien trees and shrubs increase above-ground biomass and evapotranspiration, and thereby decrease both surface water runoff and groundwater recharge. The increased biomass and evapotranspiration rates associated with most invasive alien plants arise because of their greater height, root depth and senescence, compared to the native species that they replace [Chamier, et al., 2012].

Most catchments in South Africa are water-scarce and almost all their accessible freshwater has already been allocated for use [DWA, 2010]. The shortage of available water is exacerbated by water quality problems at a national scale. These include unacceptably high nutrient concentrations [DWA, 2011b]. Additionally, anthropogenic eutrophication promotes invasion by aquatic weeds that initiates a downward spiral of invasion and that inhibits water transport; becomes a breeding ground for waterborne pathogens; and eventually also decreases water quality [Chamier, et al., 2012]. Against this backdrop of a growing scarcity of water and increasingly poor water quality, the water quality impacts of alien invasive plants are likely to worsen an already dire situation.

The impacts of invasive alien plants on water quality, while not considered to be as important as those on water quantity, should be addressed, particularly in areas where the impacts may worsen already serious water quality problems, including:

- **Implications of reductions in streamflow and groundwater storage:** Reductions in stream flow and groundwater recharge rates are brought about by increases in evapotranspiration caused by invasive alien plants; this results in reduced dilution capacity and greater concentrations of nutrients, pollutants and suspended solids in water resources.
- **Plant biomass and nutrient cycling:** Increased biomass and litter production associated with invasive alien plants could result in changes in litter chemistry, nitrogen fixation, and changes in soil chemistry in the natural biome which impact on water quality and the trophic status of receiving water resources.
- **Fire regimes, soil erosion and water quality:** Invasive alien plants alter vegetation structure, increase fuel loads and change fire behaviour, which can lead to soil damage and erosion, thereby adversely affecting water quality and enhancing occurrences of excessive nutrient-loading.
- **Aquatic alien plants and water quality:** Alien plants that invade aquatic environments can directly affect water quality by their presence in or on waterbodies.

The large-scale eradication of alien vegetation as a means to mitigate against eutrophication, however, may have the opposite effect, if care is not applied to the eradication methods. Burnt vegetation or bare soil, that contain nutrients, can easily re-enter water resources. It can also enhance erosion, which will influence sediment transport and eutrophication downstream. If eradication is done in tandem with restoration of especially the riparian zones, it will be an acceptable method, which can contribute to relieving eutrophication impacts.

3.4.2.2 Enforcement

"True public safety requires collaboration between law enforcement and the community!" Author: Betsy Hodges

3.4.2.2.1 Administrative penalties

The current penalties for non-compliance are not effectively implemented, but also not sufficiently priced to change behaviour and must be reviewed. A system of administrative penalties for water pollution offences, in particular in relation to anthropogenic eutrophication, in addition to the current criminal prosecution route, must be adopted. DWS will work in coordination with DFFE to create the relevant legislative framework and regulatory authority, to impose administrative penalties, that reflect the cost of water quality violations to society. This intervention will enable the State to achieve greater compliance with water quality regulations amongst waste dischargers. This will require an amendment to the

NWA (36:1998).[342] In line with the inter-departmental approach to eutrophication management, this regulatory authority could serve both DWS and DFFE in relation to administrative penalties for water and environmental non-compliance. Certain activities that result in water pollution, however, will still follow the criminal prosecution route, such as acts of vandalism. DWS will continue to work with DFFE on the training of inspectors, and in enforcement of legislation [DWS, 2017b, p. 49].

For more on the topic, see **CASE STUDY 4**.

CASE STUDY 4: The *"Act"* stage – Utilising administrative penalties.

Many countries of Eastern Europe, Caucasus and Central Asia use systems of administrative penalties. The offences punishable by such penalties can be roughly divided into four categories, *viz.*:

- Violation of basic environmental requirements (*e.g.,* providing false environmental reports);
- Violation of general environmental protection regulations (for air, water, forests, etc.);
- Violation of regulations concerning environmentally protected areas (*e.g.,* nature reserves); and
- Violation of environmental requirements for economic activities (*e.g.,* permit conditions).

In the last instance – penalties should be adjusted as a function of the degree to which the emission or effluent limit value in the offender's permit was exceeded. One option is to assign an incremental monetary value to each 10% of the exceedance of the limit. However, the adjustment may not be linear, especially if the pollutant can be harmful at low concentrations. Violations involving highly toxic pollutants are more serious and should result in larger penalties. Revenues from pollution charges, in most countries, are channelled into environmental funds, or special budget accounts earmarked for environmental expenditures. This makes pollution charges more attractive to environmental enforcement authorities. The system of environmental damage compensation also serves more to punish offenders and collect revenue than to remediate the environment **[OECD, 2009]**.

3.4.2.2.2 Prosecution

Legal action will be instituted as a last resort, where offenders wilfully or negligently violate regulatory requirements, and are clearly unwilling to comply with relevant statutory provisions. In addition, greater regulatory attention will be paid to waste dischargers with a history of non-compliance than to those with a history of compliance. Prosecution is viewed as an important instrument to stop the deterioration of trophic conditions in many receiving water resources, and to achieve water quality improvement. Enforcement translates into compliance assistance and incentives, and, eventually, prosecution and legal sanction. Negotiations on preventive measures, aimed at achieving relevant in-water resource water quality objectives[343] and the effective internalisation of costs,[344] will be conducted up-front to establish the compliance framework.

However, it is acknowledged that the current approach has not been successful in all cases in controlling diffuse sources of water pollution. With the greater emphasis on holistic eutrophication management,[345] which will stem from the implementation of statutory RDMs and other goals, substantial improvements will be achieved. Sources of diffuse pollution must receive greater attention[346] and should be more readily tracked while establishing and implementing geographical water quality management strategies and thematic plans.[347] Establishing water quality related "cause and effect" links[348] at local levels within sub-catchments and Water Management Areas will be central to such strategies. Any changes in the enforcement approach will have to take cognisance of the available administrative and technical capacity for the effective execution of such an approach.

342 Refer to **Annexure H** for a list of all recommended legislative amendments.
343 Refer to **Section 3.1.2.3, Part 3**: Goal setting.
344 Refer to **POLICY STATEMENT 7**: Incentive-based regulation.
345 Refer to **POLICY STATEMENT 10**: Holistic eutrophication management.
346 Refer to **Section 3.2.2.2.11, Part 3:** Diffuse pollution sources.
347 Refer to **Section 3.1.2.4.6, Part 3:** Establishment of geographical water quality management strategies and thematic plans.
348 Refer to **Section 3.1.2.2.2, Part 3:** Waste load accounting.

3.4.2.2.3 Conflict resolution

Possible areas of potential conflict that could arise as a result of the management of eutrophication, include:

- The imposing of source directed measures and controls on water use;
- The stipulation of conditions and standards for water use;
- The determination and roll-out of water quality goals;
- The execution of roles and responsibilities by different spheres of government, government departments and/or Water Management Institutions; and
- Other.

As part of the authorisation process for water use, it will be endeavoured to engage with water users to ensure that the conditions imposed on such water use are clear and justified. Any conflict that arises once the authorisation has been concluded will be escalated through to the Water Tribunal[349] for resolution.

3.4.2.3 Management review

"Continuous improvement is better than delayed perfection!" Author: Mark Twain

3.4.2.3.1 Policy and strategy revision, where necessary

Policy, strategy and law review, and corrective action, when necessary, constitute an important part of continuous eutrophication management review. Data and information forthcoming from the *"check"* stage, in the eutrophication management framework, should be used to gauge the effectiveness of the regulatory environment.[350] A review of eutrophication management should be conducted at appropriate intervals to ensure continuing suitability, adequacy and effectiveness of policy and strategy. The scope of the management review must be broad enough to account for all activities, products and services associated with the eutrophication management framework.

3.4.2.3.2 Continuous management improvement – closing the loop!

Management performance monitoring [351] ensures that role-players with identified eutrophication management responsibilities are held accountable for their actions (or inaction). In one sense, this is *"monitoring for quality control"*, but in a management context. It determines whether managers are executing their assigned tasks. It is important that management performance monitoring, although serving an end in itself, should be designed to be adaptive and responsive to the results of water quality and trophic status monitoring.[352] The ultimate overall indicators of management performance in the current context are the statutory RDMs, notably the *"resource quality"*. When Water Resource Class(es) (and RQOs/ Reserves) are determined for water resources, the degree to which these are being complied with (or movement towards such compliance is occurring) will also indicate overall management performance.

Committee structures, such as the National Water Quality Management Forum, the Anti-Pollution Task Team and the Water Quality Management Steering Committee, must be utilised as platforms to communicate and effect improvement. The line(s) of notification, with respect to eutrophication management performance and the successes or failures of the Eutrophication Management Strategy for South Africa, must be agreed and formalised.

Acknowledging that–

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[349] Refer to *Chapter 15: Appeals and dispute resolution* in the NWA (36:1998).
[350] Refer to **Section 3.3.2.3.2, Part 3:** Evaluation of the effectiveness of the regulatory environment.
[351] Refer to **Section 3.3.2.3, Part 3:** Management performance monitoring and reporting.
[352] Refer to **Section 3.3.2.2, Part 3:** Domestic status and trends monitoring and reporting.

- the management of water resources is complex and multi-disciplinary;
- decisions need to be made in situations where there frequently are insufficient, or uncertain data and information; and
- water resources are in a state of continuous change and are subject to unpredictable changes,

adaptive eutrophication management strives for continuous management improvement in a dynamic, yet systematic manner, by balancing robustness with a flexibility that allows for change when circumstances may demand this.

3.4.3 Spatial scale of implementation

The operational strategies in the *"act"* stage of the eutrophication management framework focus on corrective action, mostly at the source of the impact or at the level of the affected water resource. In some instances, corrective action may be needed in relation to the policy environment, nationally, to effect eutrophication management improvement.

3.4.4 Temporal scale of implementation

The operational strategies, being part of the *"act"* stage in the eutrophication management framework, can be conducted on an *ad hoc* basis or regularly, depending on the purpose. **TABLE 31** gives a summary of potential actions, in the *"act"* stage, which must be considered, to improve the trophic status of water resources:

TABLE 31: Operational actions to strengthen the "act" stage of the eutrophication management framework.

	SHORT TERM
1	Committee structures, such as the National Water Quality Management Forum, the Anti-Pollution Task Team and the Water Quality Management Steering Committee, must be utilised as platforms to effect improvement.
2	Achieve compliance to the requirements of in-water resource water quality objectives, *i.e.*, the RQOs and supporting RWQOs/ WQPLs, to ensure fitness-for-use of receiving water resources through the implement of adaptive, systems-based catchment eutrophication management, and adjust the control of impacts on the trophic status of receiving water resources;
3	Implement programmes to rehabilitate and manage resource water quality *"hotspots"* in priority catchments, in accordance with the relevant geographical water quality management strategies and thematic plans (if justified, utilising revenue from the WDCS);
4	Undertake targeted compliance monitoring and enforcement of key polluting sectors, specifically those that contribute to anthropogenic eutrophication;
5	Turn the performance/ functionality of five, currently non-compliant/ dysfunctional, large WwTWs around, and initiate an accompanying publicity campaign, followed by a programme to address remaining non-compliant/ dysfunctional WwTWs;
6	Roll-out intervention plans to address priority non-compliant industries;
7	Establish and implement a mechanism for applying Administrative Penalties;
8	Restructure the grant funding mechanisms and conditions for water supply and sanitation, to ensure a focus on maintaining and restoring existing infrastructure, rather than the construction of new infrastructure. Where appropriate new and innovative technology should be considered; and
9	Standardise and enforce required Operation and Maintenance (O&M) budgeting and expenditure.
	LONGER TERM
10	Develop an IWQM investment framework.
11	Devise and implement a system of alert levels.
12	Evaluate and improve the eutrophication management policy, strategy and regulatory environment at appropriate intervals.

CHAPTER 4: SUPPORTING STRATEGIES

Three strategies have been developed to support eutrophication management (**FIGURE 61**), as presented collectively through the core and operational strategies for eutrophication management, in South Africa.

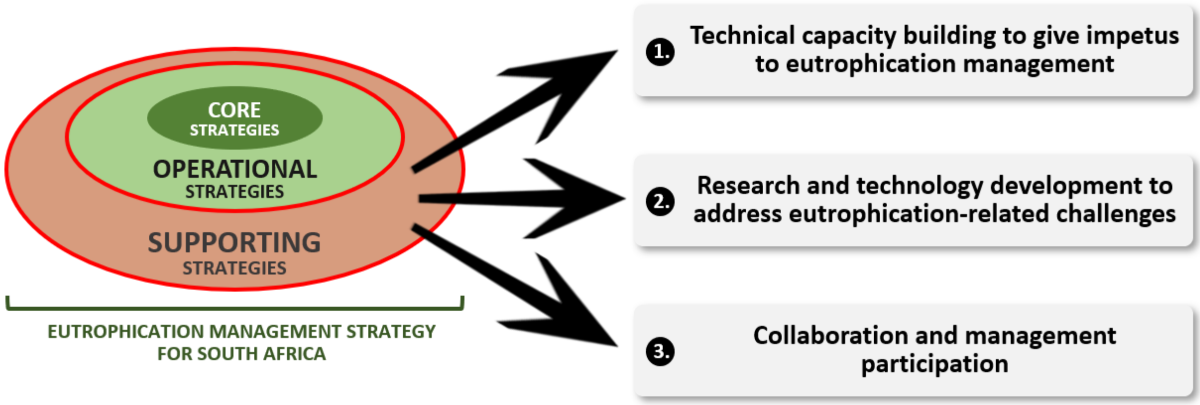

FIGURE 61: Supporting strategies for the management of eutrophication.

The three supporting strategies address:

- Technical capacity building to give impetus to eutrophication management;
- Research and technology development to address eutrophication-related challenges; and
- Collaboration and management participation,

these being discussed next.

4.1 Technical capacity building to give impetus to eutrophication management

4.1.1 Authority

National government, through the Minister of Water and Sanitation and the DWS, is the trustee of the nation's water resources and must provide the necessary sector leadership with respect to the building of technical capacity in water services and resource management, including eutrophication management. The advancement of capacity across the water value chain will require robust partnerships with stakeholders that have specific roles and responsibilities towards the common capacity building objective, with the DWS playing a strong guiding and coordinating role.

The responsibility for the harmonization of education, training and skills development, across various sectors, is vested in the Department of Higher Education and Training (DHET) and its education and training institutions and agencies. The South African Qualifications Authority (SAQA) is responsible for the National Qualifications Framework (NQF) – a set of principles and guidelines by which records of learner achievement are registered to enable national recognition of acquired skills and knowledge. The Skills

Development Act, 1998 (Act No. 97 of 1998), as amended,[353] provides the statutory framework for skills development strategies integration into the NQF. The following primary responsibilities for facilitating learning programmes (linked to occupations) reside with the Sector Education and Training Authorities (SETAs): disbursement of workplace training funds (mandatory and discretionary grants); and skills planning. For the water sector, the former Local Government Sector Education and Training Authority (LGSETA), currently the Energy and Water Sector Education and Training Authority (EWSETA), is responsible for coordinating and facilitating skills development and capacity building, in accordance with the relevant national skills and human resource development strategies and agreements between government, business and labour [DWS, 2018b, p. 158].

Through its Sector Skills Plan, the EWSETA focuses on [DWS, 2013]:

- Determining skills development priorities, after an analysis of the skills demand and trends, level of skills required and supply issues within the sector;
- Identifying a set of water-sector-specific objectives and goals that will meet water sector needs, economic or industrial sector growth strategies, and address scarce and critical skills in the sector;
- Identifying strategies, activities and resources to address sector skills development objectives and goals; and
- Reporting on the implementation of the sector skills plan.

Public service employers, in the national or provincial sphere of Government, must budget for skills development. Whereas, private sector employers, who are registered with the South African Revenue Service (SARS) and whose annual payroll, or staff complements exceeds the specified cut-off numbers, and municipalities must register with SARS to pay the skills development levy. SARS then allocates this money, via the Department of Labour and Employment, to each of the SETAs, including the EWSETA, according to the SETAs that each specific employer has registered with to facilitate the focussed training of employees in accordance with relevant sector skills plans.

Capacity building, training and skills development with respect to eutrophication requires a multiplicity of authorities and agencies who represent many related interests and mandates.[354] Competencies (sectors), which are relevant, include: ♦ agriculture; ♦ disaster management; ♦ education; ♦ the environment; ♦ health; ♦ human settlements; ♦ infrastructure; ♦ land use and development planning; ♦ mining; ♦ research and development; and ♦ water and sanitation. These listed competencies are linked to responsible authorities in Chapter 5 of Part 3 that addresses ***"Governance"***, and that gives additional resolution to the assigning of roles and responsibilities in a eutrophication management context.

4.1.2 Prescribed approach

Capacity creation, with respect to the management of anthropogenic eutrophication, must:

- Establish *"individual capacity"* by enabling people to better perform defined functions, as individuals, through improved technical skills and professional understanding, and as groups by aligning their activities to achieve common purpose, as articulated through the goal for eutrophication management in South Africa;
- Enable institutions through the creation and maintenance of the requisite *"institutional capacity"* or *"organisational capacity"* (*i.e.,* the structure, processes and resources of the organisations themselves), to plan for, and manage anthropogenic eutrophication; and

[353] Hereafter referred to as SDA (97:1998).

[354] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

- Create appropriate *"environmental capacity"* through the establishment of suitable external enablers, such as sector policy, strategies, plans, legislation, funding and institutional arrangements for effective regulation and seamless accountability.

The Eutrophication Management Strategy for South Africa endorses the point of view that capacitation at all three levels is vital for effective eutrophication management. However, capacity at the individual level is the most fundamental element of capacitation and forms the foundation for organisational and environmental capacity. Whereas discussions elsewhere in this document deal with elements of *"organisational capacity"*[355] and *"environmental capacity",*[356] the ensuing discussions here will focus on *"individual capacity"*.

The water and sanitation sector is dependent on high levels of professionals and technicians. A need for professional experience on site and continual professional development exists. The skills and capacity required by municipalities to deliver and maintain water and sanitation services sustainably remain inadequate and require urgent attention. Municipal skills and capacity challenges are compounded by the difficulty of attracting qualified professionals to rural and smaller municipalities. The shortages of specific critical skills must be addressed because this deficit is detrimental to the management of eutrophication, within various water sector institutions across the water and sanitation business value chain.[357] Focus is placed on four key areas that have been identified, namely– (1) engineering and sciences; (2) artisans and process controllers; (3) socio-economic and environmental skills; as well as (4) emerging professions [DWS, 2013]. Over-reliance on consultants to address most general technical staff shortages must be avoided.

Notwithstanding all the issues and challenges, the Sector has made considerable progress towards addressing skills and capacity gaps throughout the water value chain. Several initiatives have been successfully implemented, including:

- The ***Framework Programme for Education and Training in Water*** (FETwater) – an initiative of the DWS and the WRC, in collaboration with UNESCO and the Flemish Government [UNESCO, 2021]. FETwater provides an overarching programme within which technical capacity creation for eutrophication management can be undertaken and strengthened;
- The ***DWS Learning Academy*** continues to offer bursaries and to develop interns (engineers and scientists) with the goal of registering them as professionals after three to five years. The Academy has won the Billiton prize for the Best Capacity Building Programme in 2012 [DWS, 2013, p. 97]; and
- The ***2020 Vision for Water and Sanitation Education Programme***, which was initiated in 1996 with the aim to strengthen awareness on integrated water resources management. Learners were identified as the target group for the Programme because *"you educate a child to educate the nation"*. The Programme is advocated through eight projects and five of them are in the form of competitions. All the action projects run from district to provincial adjudications, which culminate in National Adjudication every year [DWS, 2021].

4.1.3 Spatial scale of implementation

Technical water services and resource management related capacity building is undertaken in many ways. Modes of capacity creation of individuals, include–

- formal training at academic institutions;
- informal on-the-job training by mentors at the level of the organisation; as well as

[355] Refer to **Section 4.3, Part 3**: Collaboration and management participation, in combination with **Chapter 5, Part 3**:Governance.

[356] Refer to **Section 3.3.2.3.2, Part 3:** Evaluation of the effectiveness of the regulatory environment, in combination with **Section 3.4.2.3.1, Part 3:** Policy and strategy revision, where necessary.

[357] Refer to **POLICY STATEMENT 18**: Technical capacity to take eutrophication management action.

- *"outward"* training programmes, where capacity building support is provided to the sector in general; or
- *"inward"* training, where internal training programmes are developed and maintained; and
- initiatives, which get established because of national, regional or local priorities for capacity creation.

Irrespective of the modes of capacity creation that are available, it is essential that relevant capacity building programmes devote sufficient attention to eutrophication-related capacity building objectives, proportionate to the levels of impact, of it, being experienced on ecologically sustainable development.

4.1.4 Temporal scale of implementation

Specific technical capacity is required to facilitate eutrophication management for certain well-defined scenarios in the short term. However, more sophisticated capacity will be required in the longer term to enable a more complete implementation of the NWA (36:1998). There are also changing demands on institutional capacity, as roles and responsibilities evolve, and water resource management becomes more decentralised. An urgent need exists to facilitate better eutrophication management in the short term. However, this strategy also focuses on moving gradually over time towards doing things better, even if this requires radical changes in the capacity creation philosophy within Government. In effect, the short-term requirements should be met using instruments that are currently available and in the spirit of adaptive management.[358] The long-term strategy must be to move towards more fundamental *"knowledge creation"*. In practical terms, knowledge can be defined as the capacity for informed action. This is required, both within Government and externally.

Various technical capacity building interventions must be considered and developed, or, where necessary, refined and improved for implementation (**TABLE 32**):

TABLE 32: Supporting actions to strengthen technical capacity building.

	SHORT TERM
1	There is inadequate human resource planning, *i.e.,* a lack of succession planning, weak retention strategies and the inadequate induction of professional entrants. Staff turnover is a normal phenomenon, but the Department should take appropriate measures to ensure that it does not lead to an unacceptable loss of institutional memory. These may include the option of retain offers as well as the option for staff to become specialist scientists. Human resource planning must be improved to protect, develop and extend existing technical eutrophication management capacity;
2	Investing in good training programmes to ensure continuous learning and a clear professional development path for incumbents is important. This will require the reviving (and inclusion of an introductory section on eutrophication) of some of the old water quality training programmes, such as the Water Quality Management Orientation Course. Whilst the introductory courses could be made available in-house, financial resources must be allocated to support the development and roll-out of more detailed and phased programmes that address the technical and detailed complexities of IWQM, and specifically reservoir limnology and eutrophication management, to improve performance, productivity, skills development, and to gain and increase knowledge;
3	Define (and reinstate in some cases) career paths with defined training and on the job experience to build a cadre of sector professionals;
4	Provide bursaries and/or learnerships pertaining to water quality management at tertiary institutions;
5	Develop and implement a programme for recruiting and retaining experienced and qualified technical and managerial staff with technical qualifications in South Africa, or abroad; and
6	Establish and strengthen IWQM awareness creation campaigns at national, Water Management Area and municipal levels.

[358] Refer to **Section 3.4.2.3.2, Part 3**: Continuous management improvement – closing the loop!

LONGER TERM	
7	There is a shortage of specific critical skills within various institutions, across the water value chain, *i.e.,* engineering skills, artisans, socio-economic, environmental health, and management skills, which also negatively impact on the management of eutrophication. The demands for these skills should be addressed;
8	Develop and implement a capacity building programme for officials in DWS, CMAs and other sector departments, and for the private sector and civil society on systems based, adaptive IWQM, applicable legislation and law enforcement;
9	The DWS' Learning Academy initiative in conjunction with on-the-job training and mentorship has made strides in filling the skills gap within the water sector and should continue to receive the necessary support.

4.2 Research and technology development to address eutrophication-related challenges

4.2.1 Authority

The three core partners – the DWS, the Department of Science and Innovation (DSI) and the WRC – are the national drivers of water research, development and innovation.[359] Linked to these three core partners is a range of traditional research role-players, including the National Research Foundation (NRF), the Technology Innovation Agency (TIA), Research Councils, Units and Universities [DWS, 2018b]. Many other organisations are pivotal in scaling up, testing and deploying new innovations: These include utilities, municipalities, the private sector and non-profit organisations.

The WRC currently houses a portfolio management unit funded by the DSI for national water research, development and innovation coordination and implementation [DST, 2015]. The functions of this unit include:

- Prioritisation and project management;
- Developing partnerships and sourcing investment;
- Promoting the visibility of water research successes;
- Monitoring and evaluation; and
- Ensuring effective governance and implementation.

Competencies (sectors), which are relevant here, include: ♦ education; ♦ research and development; and ♦ water and sanitation. These competencies are linked to responsible authorities in Chapter 5 of Part 3 that addresses ***"Governance"***, and that gives additional resolution to the assigning of roles and responsibilities in a eutrophication management context.

4.2.2 Prescribed approach

Whilst there is a rich institutional and skills environment to draw from, water research, development and innovation continue to face a range of challenges, including: poor coordination; ineffective synergising of activities between institutions; a weak understanding of the role of all water sector organisations in driving innovation and shifting theoretical solutions to practise; inability to scale-up solutions to market readiness; and highly limited funding for innovation (particularly in the scaling-up and deployment stages). This results in many solutions that emerge from the research and development space not being implemented in practise. For South Africa to be ready for the future, the innovation chasm where emerging solutions fail to be tested at scale must be addressed, or solutions be developed into viable businesses that are able to engage with different public and private sector role-players [DWS, 2018b].

[359] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

The National Water Research, Development and Innovation (RDI) Roadmap, 2015 was adopted as the implementation plan for NWRS2's Chapter 14 that deals with *Research and Innovation*, which specifies the following guiding principles for water research, development and innovation implementation [DWS, 2013]:

- Research and innovation must be focussed and aligned to achieve an overall vision;
- Research and innovation cuts across traditional research boundaries, in line with agreed high-level objectives;
- Research and innovation should be well coordinated within the sector and the coordination role must be well established;
- Research and innovation should be geared towards aligning products, services and knowledge that will contribute to practical solutions to issues in the water sector, and thus promote sustainable development;
- Knowledge derived from water research must inform policy development and strategic decision-making at all levels of government and across the water value chain; and
- Transformation, equity and empowerment of marginalised groups inform the design of research and development projects.

To develop and encourage water quality research and innovation, including eutrophication-related research and innovation, in South Africa, the DWS and the WRC will lead the sector in developing a national water quality research, development and innovation plan that aligns applied research priorities throughout the water value chain to ensure that water research directly contributes to the resolution of water sector challenge and addresses emergent areas like emerging pollutants.[360] The role of South Africa's academic institutions, and independent research organisations, will be critical in the development of this plan [DWS, 2017b, p. 63].

4.2.3 Spatial scale of implementation

The WRC has been extensively involved in eutrophication-related research since its inception, and has to date published more than 84 research reports that focus on eutrophication, its treatment and its management [Frost & Sullivan, 2010]. The profile of the eutrophication-related research undertaken by the WRC can be organised into six categories, as follows:

The eutrophication phenomenon: The emphasis is on characterising eutrophication, the processes that give rise to it, the reasons for its occurrence and policy approaches for addressing the phenomenon;

The sources of eutrophication: The causes of eutrophication are addressed in detail. The impacts of factors that cause a system to become eutrophic are analysed in depth with the help of field studies and simulations;

The management of eutrophication: Methods and measures for controlling and managing the problem across various freshwater systems are researched. Innovative approaches and their viability in a South African and global context are assessed;

Blue-green algae (cyanobacteria): Blue-green algae, potentially a toxic and dangerous indicator and consequence of eutrophication, are studied in detail. Emphasis is placed on monitoring the nature, causes and effects of blue-green algae, as well as their detection and management;

Drinking water treatment adaptations: The consequences of eutrophication for drinking water treatment and the adaptation of drinking water treatment processes to remove algae and associated toxins, tastes and odours, are addressed; and

[360] **POLICY STATEMENT 16:** Promotion of eutrophication-related research.

Wastewater treatment to remove phosphorus: A major cause of eutrophication, namely high phosphate levels in effluent from WwTWs released into freshwater systems, is addressed as a proactive approach to managing the problem and thereby reducing pressure on the symptomatic treatment of eutrophication in already affected systems.

Over time, the research focus shifted from understanding the scope and causes of eutrophication towards its management and treatment. Overall, however, the research focus was almost equally spread among the six categories, with no one category receiving a disproportionate amount of attention [WRC, 2011].

4.2.4 Temporal scale of implementation

The National Water RDI Roadmap provides a 10-year plan and sets investment priorities for water research, development and innovation. The National Water RDI Roadmap envisions: ***"South Africa to become a leader among middle income countries in the development and deployment of water management practices and technologies and to compete with leading countries in providing sustainable solutions"***.

Various research and technology development interventions must be considered and developed, or, where necessary, refined and improved for implementation (**TABLE 33**):

TABLE 33: Supporting actions to strengthen research and technology development.

	SHORT TERM
1	Develop, demonstrate, validate and encourage the use of alternative sanitation, such as water-less and off-grid sanitation solutions, and urine-diversion toilets. This potentially includes the development of strategies and regulations to mainstream appropriate sanitation technology;
2	Investigate recent innovative treatment technologies to improve water quality;
3	Provide sufficient and sustained funding for appropriate applied research;
4	Develop and demonstrate appropriate domestic and industrial wastewater technologies for cost effectiveness, energy efficiency and beneficiation;
5	Initiate a case study *"pilot"* approach to upgrading the treatment processes employed in WwTWs;
6	Determine the typical relative nutrient-loading point and diffuse contributions of different land use sectors.
7	Invest in communities of practice that bring together built and ecological infrastructure experts and raw water quality improvement solutions;
8	Continue to do research on land use impacts on water linked ecosystems and raw water quality;
9	Test a suite of information and communication technology, and citizen science tools for data sourcing; and
10	Review all relevant guidelines and R&D products to understand where training modules need to be developed around new knowledge.
	LONGER TERM
11	DWS and the WRC will lead the sector in developing a national water quality research, development and innovation plan;
12	Continue to invest in understanding emerging contaminants (detection and treatment) in order to improve the transition to reuse, reclamation and recycling of return-flow water; and
13	Support a hydrological monitoring centre for South Africa to re-establish a robust data, monitoring and information capability for more effective water resources planning and climate change forecasting in future.

4.3 Collaboration and management participation

4.3.1 Authority

The DWS has a lead role to play within the ambit of *"eutrophication management"*, especially with respect to sector coordination and support, regulation and oversight. The DWS is supported by Water Management and Services Institutions to address a range of operational and water management functions – many of which may influence the trophic status of receiving water resources. Additionally, many other government departments, within any of the spheres of government, may also have regulatory responsibilities, especially those that deal with aspects of land use planning and management, which potentially could affect anthropogenic eutrophication. Different mandates and regulatory responsibilities, therefore, may influence the country's water resources from a eutrophication perspective, showing that collaboration and management participation is vital to achieving the common Eutrophication Management Goal.

The competencies (sectors) that are involved in aspects of the management of eutrophication were elaborated throughout Part 3. Collaboration and management participation between the authorities that are responsible for these competencies, and the private sector and civil society are prerequisites for effective eutrophication management.

4.3.2 Prescribed approach

In line with the universal notion for holistic thinking and more integrative decision-making in natural resource management, water quality management in South Africa also had to shift along this continuum to enable the consideration of relevant detail in a bigger-picture context (**FIGURE 62**). Likewise, the management of eutrophication increasingly requires the consideration of multiple interrelated factors, including ecosystem complexities, socio-economic linkages and diffuse impacts from land to name but a few, when making management decisions. This growing need for holistic thinking, consequently, is increasingly emphasising the need for collaboration and management participation.

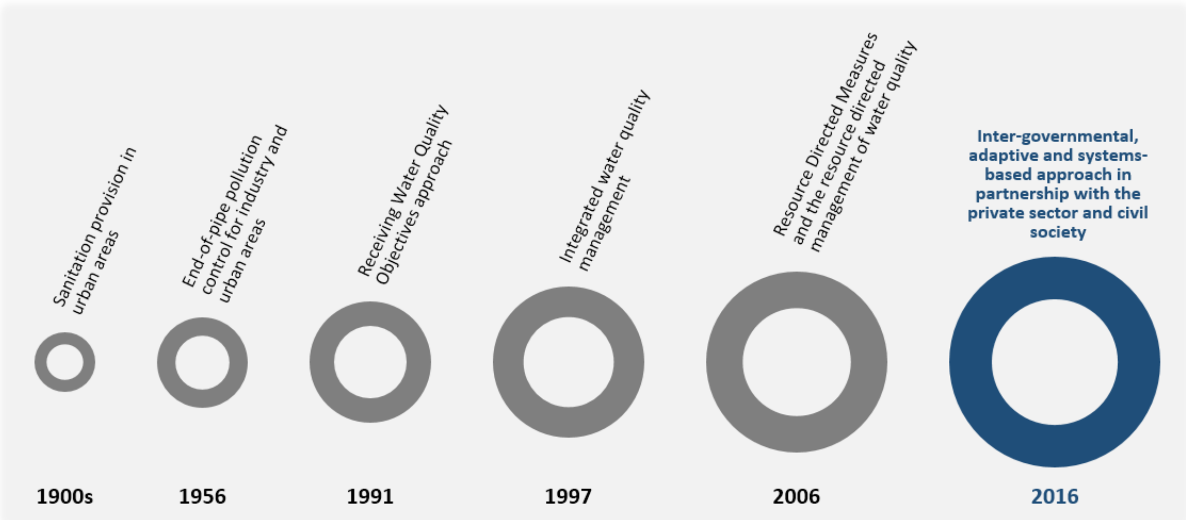

FIGURE 62: The management of eutrophication is part of a water quality management approach that, over time, has evolved into an *"inter-governmental, adaptive and systems-based approach that is executed in partnership with the private sector and civil society"* [DWS, 2017b, p. 13].

The success of eutrophication management depends on appropriate collaboration and support that can be harnessed to aid with the implementation and execution of the *Eutrophication Management Strategy for South Africa*. This effort should be orchestrated into meaningful relationships, which translate into ongoing cooperation. The potential for conflict must be limited. An enabling environment and conducive mechanisms should be promoted to facilitate partnerships between public, private and community organisations, other national departments, provincial and local authorities, non-governmental organisations, the private sector and civil society, as well as international governmental and aid organisations.[361]

Efforts will be undertaken to strengthen the management of eutrophication within the DWS. Successful functioning of the DWS's structured matrix management systems requires concerted efforts to achieve internal coordination between Head Office and regional offices and among regional offices, and must include the nomination of **(a) Eutrophication Management Champion(s)**, preferably at both head and regional office levels. The role of these Champion(s) will *inter alia* be to assist with eutrophication management alignment; act as anchor for facilitating the inter-departmental approach to eutrophication management; and built capacity [362] across DWS offices. Additionally, suitable **intra-** and **inter-departmental standing committees** should be considered (**TABLE 34**) and established to support the DWS with the alignment of eutrophication-related decisions; improvement of performance; sharing of information; and discussing matters of roles and responsibilities. Agreed procedures, such as memoranda of understanding, could be considered and instituted in the case of inter-departmental collaboration with other line function departments that are involved in the management of aspects of eutrophication. Eutrophication, however, cannot be treated separately from the broader integrated water quality management function, and must be dealt with in an integrated manner. All relevant departments and government agencies will be held accountable for their actions in relation to the IWQM Policy, and the DWS will report annually, in its annual report, on the effective implementation of the government-wide approach towards IWQM, specifically also including the management of eutrophication.

TABLE 34: Intra- and inter-departmental water quality management standing committees to also serve as vehicles for addressing and improving the management of eutrophication [DWS, 2016a, p. 33].

IWQM COMMITTEE	DESCRIPTION OF COMMITTEE AND POTENTIAL TO IMPROVE THE MANAGEMENT OF EUTROPHICATION [363]
Water Quality Functional Management Committee	This committee should be chaired by the Chief-Director: Water Use Compliance Monitoring and Enforcement and can consist of Chief Directors from the Branch: Water Resource Management; Branch: Regulation, Compliance and Enforcement, as well as Provincial Heads. Key line function Directors and Scientist Managers could be included in this committee to provide additional technical capacity and insights. This committee will have oversight over the IWQM function, **and will, therefore, also make recommendations with respect to eutrophication.**
Regional Water Quality Functional Management Committees	Within each DWS Regional Office this committee will pull together the various line functions that support IWQM within their respective WMAs. This committee will be chaired by the Director: Regulation. The participation will vary according to the structure of the DWS Regional Offices and would include CMAs, if established. **This committee will thus also aim to ensure eutrophication alignment in approach and coordination within the WMA.**

[361] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

[362] Refer to **Section 4.1, Part 3**: Technical capacity building to give impetus to eutrophication management.

[363] For DWS intra-departmental arrangements, the DWS organisational structure, as approved on 26 September 2022 by the Hon. Minister S. Mchumu, was consulted.

IWQM COMMITTEE	DESCRIPTION OF COMMITTEE AND POTENTIAL TO IMPROVE THE MANAGEMENT OF EUTROPHICATION [363]
Inter-Governmental Task Teams	Typically established to resolve specific challenges, such as the current task team established for Mine Closure and Mine Water Management. These task teams provide the vehicle for cooperative government approaches and, as such, are largely advisory in nature, reporting back to parent Departments. Due to the nature of these task teams the chairing of these meetings should be rotated appropriately. **This task team will create awareness on eutrophication and promote collaboration and management cooperation among key government role-players.**
National – Regional Water Quality Operational Committees *(National Water Quality Management Forum)*	This committee will provide a bridge between the DWS Head Office line functions and the Regional Offices/ CMAs and would replace what was previously the Water Quality Deputy-Director's meeting. The committee will be chaired by the Chief Director: Water Use Compliance Monitoring and Enforcement and will focus upon operational business matters, with a focus on ensuring strategic intent in WMAs, as part of the national drive to implement the IWQM Policy and Strategy (2017). A key focus will be on continual and adaptive improvement of approaches towards realising impacts in catchments. Hence, the focus of this committee would be upon the **operational dimensions of IWQM, which will include eutrophication**.
(Anti-Pollution Task Team - APTT)	The APTT will be chaired by the Chief Director: Water Use Compliance Monitoring and Enforcement and will co-ordinate and integrate immediate efforts for the improved management of water resource quality in South Africa, **with turn-around interventions for high-risk pollution hotpots and water use pollution activities**. The APTT will identify remedies to mitigate pollution caused by all water use sectors and must achieve its mandate by engaging other organs of state and water users.
(Water Quality Management Steering Committee)	The Water Quality Management Steering Committee will be chaired by the Chief Director: Water Use Compliance Monitoring and Enforcement and will deal with strategic matters, focusing on co-ordination and integration of water quality management and the **implementation of the IWQM Policy and Strategy (2017)**.
Integrated Water Quality Catchment Management Committees	Chapter 7 of the NWA (36:1998) and policy allow for the establishment of Catchment Management Committees, either based spatially; focused on a technical issue, such as IWQM; or in fact both. These provide a vehicle for on-the-ground operational management and involves a range of relevant or key stakeholders, together with officials. The modalities of these committees are very much in accordance with the needs for IWQM, **including the management of eutrophication**, at the local level. These committees will obtain strategic guidance from the Regional Water Quality Functional Management Committee, as well as more operational guidance from the National-Regional Water Quality Operational Committee.

In line with the principles of subsidiarity[140], the management of eutrophication is best performed at a local and catchment scale. In this regard, the CMAs will utilise Catchment Management Forums (CMFs) and Catchment Committees, and will collaborate with Water User Associations (WUAs) to support participatory eutrophication management. The challenge of the delay in finalising the establishment of CMAs, and other Water Management Institutions, hampers improved participatory management[105]. Catchment Management Forums should be employed to promote collaboration with stakeholders. Goal setting[364] and visioning[365] will be established in a consensus-seeking manner, involving stakeholders in order to generate a sense of cohesion and common purpose amongst role-players with diverse interests in the water resource [DWAF, 2006c].

The institutional arrangements and other arrangements created, to facilitate collaboration and management participation, would be of limited value, if not augmented with capable and competent employees, and supported by adequate regulatory and operational instruments. Hence, the drive to build

[364] Refer to **Section 3.1.2.3, Part 3:** Goal setting.

[365] Refer to **Section 3.1.2.2.4, Part 3**: Visioning to propose levels for water resource protection.

technical capacity[366] and to develop regulatory and other operational instruments[367] to assist with the management of eutrophication.

The DWS and CMAs will provide the necessary national strategic guidance, oversight and leadership on transboundary eutrophication-related matters, collaborating with bodies concerned with international water management, as may be necessary.

Business has a corporate social responsibility and should play a role in limiting the effects of eutrophication by engaging in, or supporting volunteering or ethically-oriented practices. Highly focused, fit-for-purpose, civil society and corporate business partnerships to assist with the management of eutrophication can be considered and created in cases where such partnerships will lead to improvements of the trophic status of water resources. The concept of water stewardship should be promoted. Partnerships with civil society must be strengthened and further developed.

The creation of a *"community of practice"* for eutrophication management, consisting *inter alia* of academia, experts and practitioners, will provide a platform for the fostering of eutrophication-related knowledge. Such a *"community of practice"* can be utilised for the promotion of collaboration, research[368], knowledge development and knowledge sharing.

4.3.3 Spatial scale of implementation

Collaboration and management participation applies to the various scales of eutrophication management. These scales range from the source specific scale to the local, regional or catchment, and the national scale to the transboundary and international scale.

4.3.4 Temporal scale of implementation

The following collaboration and management participation interventions must be considered for implementation, to improve the trophic status of water resources (**TABLE 35**):

TABLE 35: Supporting actions to strengthen collaboration and management participation.

	SHORT TERM
1	Participate and strengthen intra-departmental structures for IWQM to also address the management of eutrophication, including the National Water Quality Management Forum (NWQMF), the Anti-Pollution Task Team (APTT) and the Water Quality Management Steering Committee, to ensure efficient coordination and joint action, supported by regular reporting;
2	Nominate (an) Eutrophication Management Champion(s), preferably at both Head and Regional Office levels;
3	Strengthen and foster strategic sector partnerships, and enable active participation of civil society; and
4	Establish and support Catchment Management Forums.
	LONGER TERM
5	Provide eutrophication support to Integrated Water Quality Catchment Management Committees, if established;
6	Provide eutrophication support to the Inter-Governmental Task Team on IWQM, once established;
7	Provide eutrophication support to the Regional Water Quality Functional Management Committees, once established; and
8	Provide eutrophication support to the Water Quality Functional Management Committee, once established.

366 Refer to **Section 4.1, Part 3:** Technical capacity building to give impetus to eutrophication management.
367 Refer to **Section 3.2, Part 3:** The *"do"* stage.
368 Refer to **Section 4.2, Part 3:** Research and technology development to address eutrophication-related challenges.

CHAPTER 5: GOVERNANCE

"Water governance" can be defined as: *"The range of political, social, economic and administrative systems by which institutions and organisations are directed and controlled to develop and manage water resources and services at different levels of society. It is concerned with structure and processes for decision-making, accountability, control and behaviour at the top of such institutions or organisations. Governance influences how an organisation's objectives are set and achieved, how risk is monitored and addressed, and how performance is optimised"* [adapted from DWAF, 2006f]. Good water governance depends upon predictability, inclusion, representivity, accountability, efficiency, effectiveness, social equity and justice. It requires open and transparent policy making, a professional bureaucracy and a strongly engaged civil society [DWAF, 2006f].

Chapter 3 of the Constitution (108:1996) introduces the concept of ***"Cooperative governance"*** and requires that the three distinctive, interdependent and interrelated spheres of government (and all organs of state) must conduct their activities in the national interest and within the spirit of cooperation. ***"Cooperative government"***, importantly, only constitutes one part of the wider concept of *"governance"*, and includes civil society and the private sector[369] [DWAF, 2006f]. This is particularly important in the context of eutrophication, where the national, provincial and local spheres of government make and administer legislation, often with wide-ranging impacts on water resources and, specifically, also potentially on the trophic status of receiving water resources.

There is, and likely will continue to be, significant change of the institutional arrangements, water governance and organisational responsibilities in the water sector. However, without clarity (and strengthening) in these areas, particularly around defined **roles and responsibilities**, the possibilities for effective management and decision making, with respect to water resources and their quality, will be seriously jeopardised. This chapter, therefore, focuses on roles and responsibilities, specifically with respect to the identification of the various responsible authorities who play important roles and who may potentially impact on the trophic status of water resources. **TABLE 36** aims to clarify mandates in relation to eutrophication and governance, against the backdrop of much needed collaboration and management participation.[370] A number of competencies were identified for the purposes of sketching the *"eutrophication governance"* landscape. These are listed alphabetically (column 1); were linked to relevant authorities (column 2); and contextualised, from a eutrophication management perspective, (column 3):

[369] Collaboration with the private sector and civil society is addressed in **Section 4.3, Part 3:** Collaboration and management participation**.**

[370] Refer to **POLICY STATEMENT 19**: Cooperative eutrophication management.

TABLE 36: Competencies (sectors), relevant authorities and their roles in eutrophication management.

COMPETENCY[371]	RELEVANT AUTHORITY	ROLE IN THE MANAGEMENT OF EUTROPHICATION
Agriculture	▶ *Department of Agriculture, Land Reform and Rural Development (DALRRD); and* ▶ *Provincial departments of agriculture*	Are responsible for the implementation of the Conservation of Agricultural Resources Act, 1983 (Act No. 43 of 1983)[372] and for agricultural policy. Responsible for promoting agricultural practices that reduce water pollution, including anthropogenic eutrophication. In reviewing the CARA (43:1983), the DALRRD and provincial departments will consider the need to reduce excessive nutrient-loading arising from current agricultural practices. The DALRRD and provincial departments will, in line with the approach outlined in the draft Policy on Sustainable Agriculture, promote sustainable agricultural practices that, amongst other things, will contribute to the reduction of nutrient-loading arising from agricultural areas. The DALRRD and provincial departments will also ensure improved enforcement.
	▶ *Department of Water and Sanitation (DWS); and* ▶ *Catchment Management Agencies (CMAs)*	Must ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all persons. Are responsible for the authorisation of agricultural water use, including the regulation of agriculture-related industrial water use and intensive animal units, and, thus, must protect water resources against both agricultural point and diffuse impacts. The DWS must ensure that water resources remain fit for agricultural use.
	▶ *Department of Forestry, Fisheries and the Environment (DFFE); and* ▶ *Provincial departments of environmental affairs*	Are responsible for the implementation of the NEMA (107:1998) and for conducting EIAs of listed activities. The DFFE must ensure, in consultation with DWS and CMAs, that water quality impacts, including excessive nutrient-loading, are sufficiently dealt with in EIAs and through a co-ordinated compliance monitoring and enforcement approach with the DWS.
Disaster management	▶ *Department of Cooperative Governance and Traditional Affairs (CoGTA);* ▶ *National Disaster Management Centre (NDMC)*	Supports inter-governmental cooperation. Must promote an integrated and co-ordinated system of disaster management, with a special emphasis on prevention and mitigation, by national, provincial and municipal organs of state, statuary functionaries, other role players and communities. Water pollution, including excessive nutrient-loading and sewage spills, can cause disasters; a *"disaster"* being defined as: *"the progressive or sudden, widespread or localised, natural or human-caused occurrence which– causes or threatens to cause– death, injury or disease; damage to property, infrastructure or the environment; or disruption of the life of a community; and which is of a magnitude that exceeds the ability of those affected by the disaster to cope with its effects using their own resources"*.
	▶ *Department of Water and Sanitation (DWS)*	Must ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all persons; Must ensure and maintain fitness-for-use of water resources; Responsible for the establishment of national monitoring systems to provide information to Water Management Institutions, the NDMC, water users and the public, *inter alia* for public safety and disaster management purposes.

[371] The *"competencies"* listed in this column link to the competencies listed under the *"Authority"* headings, discussed in the individual strategies under Chapters 2, 3 and 4, to address the *"Who?"* that carries responsibility.

[372] Hereafter referred to as CARA (43:1983).

COMPETENCY[371]	RELEVANT AUTHORITY	ROLE IN THE MANAGEMENT OF EUTROPHICATION
Education	▶ *Department of Basic Education (DBE)*	Responsible for providing learner and teacher support materials; developing skills for a changing world; planning for the migration of the early childhood development function from the social development sector to the basic education sector; providing support to improve matric completion rates; preparing learners for jobs; and facilitating the increase in supply of quality teachers. Learning includes environmental awareness, which should also address aspects of eutrophication.
	▶ *Department of Higher Education and Training (DHET)*	Must develop capable, well-educated and skilled citizens who are able to compete in a sustainable, diversified and knowledge-intensive international economy, which meets the development goals of the country, by: reducing skills bottlenecks, especially in priority skills areas; improving participation rates in the system; correcting distributions in the shape, size and distribution of access to post-school education and training; and improving the quality and efficiency in the system, its subsystems and institutions. Additionally, DHET is over-all responsible for the harmonization of education, training and skills development, across sectors, including the water sector, including skills to control and manage anthropogenic eutrophication.
	▶ *Energy and Water Sector Education and Training Authority (EWSETA)*	Is charged with the responsibility of coordinating and facilitating skills development and capacity building in the water sector, in accordance with the relevant national skills and human resource development strategies and agreements between government, business and labour.
	▶ *Department of Water and Sanitation (DWS);* ▶ *Catchment Management Agencies (CMAs)*	DWS must provide the necessary sector leadership with respect to the building of technical water services and resource management capacity, including capacity to manage eutrophication. CMAs play a supporting and operational role.
	"Research" authorities, such as ▶ *Water Research Commission (WRC);* ▶ *Department of Science and Innovation (DSI);* ▶ *Etc.*	Works closely, *inter alia* with other research and academic institutions and organisations to develop knowledge within the water sector, explore new thinking and to develop applied solutions to problems, including eutrophication knowledge development, thinking and addressing challenges.
Environment	▶ *Department of Forestry, Fisheries and the Environment (DFFE); and* ▶ *Provincial departments of environmental affairs*	Are responsible for the implementation of the environmental management acts, including NEMA (107:1998), and for conducting EIAs for listed activities. The DFFE must ensure, in consultation with the DWS and CMAs, that water quality impacts, including excessive nutrient-loading, are sufficiently dealt with in EIAs. DFFE, with DWS and other relevant regulators, are also responsible for a co-ordinated compliance monitoring and enforcement approach to enforce the SEMAs.
	▶ *South African National Biodiversity Institute (SANBI)*	Leads and coordinates research, and monitors and reports on the state of biological diversity in South Africa. The institute provides knowledge and information, gives planning and policy advice and pilots best-practice management models in partnership with stakeholders. Engages in ecosystem rehabilitation and restoration, leads the human capital development strategy of the biological diversity sector and manages the National Botanical and Zoological Gardens as 'windows' to South Africa's biological diversity for enjoyment and education. Eutrophication threatens biological diversity and must be controlled in a manner that promotes ecologically sustainable development.

COMPETENCY[371]	RELEVANT AUTHORITY	ROLE IN THE MANAGEMENT OF EUTROPHICATION
	▶ *South African National Parks (SANParks)*	Responsible for inclusive nature conservation and to advance nature conservation policies in line with the National Development Framework for Sustainable Development and the National Development Plan. Eutrophication adversely affects *"nature"*, *i.e.,* aquatic ecosystems, biological diversity, etc.; sense of place; and tourism.
	▶ *Department of Water and Sanitation (DWS);* ▶ *Catchment Management Agencies (CMAs)*	Must ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all persons; Must ensure and maintain fitness-for-use of water resources, including fitness-for-use for the aquatic ecosystem. Must implement the Mitigation Hierarchy for eutrophication management. Must compile and publish sector offset guidelines for wetlands and water quality to enable the rolling out of offsetting for eutrophication management.
Health	▶ *Department of Health (DOH)* ▶ *Provincial departments of health*	Have a critical role to play in epidemiological studies to understand the impacts of poor water quality, including eutrophication and the sub-standard treatment of wastewater, on human health.
	▶ *Department of Water and Sanitation (DWS);* ▶ *Catchment Management Agencies (CMAs)*	Must ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all persons; Must ensure and maintain fitness-for-use of water resources to *inter alia* protect human health and wellbeing. The Basic Human Needs Reserve constitutes a right and protects human health.
Human settlements	▶ *Department of Human Settlements*	To facilitate the creation of sustainable human settlements and improve the quality of household life and to determine, finance, promote, communicate and monitor the implementation of housing and sanitation programmes.
	▶ *Department of Water and Sanitation (DWS);* ▶ *Water Services Institutions*	To ensure that the country's water resources are protected, used, developed, conserved, managed and controlled by regulating and supporting the delivery of effective water supply and sanitation. This is done in accordance with the requirements of water-related policies and legislation that are critical in delivering on people's right to have sufficient food and water, growing the economy, and eradicating poverty.
Infrastructure	▶ *The Presidency*	The Presidential Infrastructure Coordinating Commission (PICC) was formed to provide for the facilitation and coordination of the National Infrastructure Plan which is of significant economic and social importance to the country; To ensure that infrastructure development is given priority in planning, approval and implementation; To ensure that the development goals of the State are promoted through infrastructure development; To improve the management of such infrastructure during all life-cycle phases, including planning, approval, implementation and operations.
	▶ *Department of Works and Infrastructure;* ▶ *Provincial departments of public works;* ▶ *Municipal Public Works*	Contributes to the national goals of job creation and poverty alleviation through public works programmes; Ensures the effective management of the state's immovable assets; The Constitution (108:1996) gives concurrent functions to municipalities for municipal public works, with either national or provincial government able to regulate how they exercise these functions in line with applicable norms and standards. Most municipalities carry out their own infrastructure planning and delivery functions in relation to the services they provide, such as water, sanitation, municipal roads and electricity distribution. The operation and maintenance of the WwTWs of many municipalities are currently unacceptable.

COMPETENCY[371]	RELEVANT AUTHORITY	ROLE IN THE MANAGEMENT OF EUTROPHICATION
	▶ *Department of Cooperative Governance and Traditional Affairs (CoGTA);* ▶ *Municipal Infrastructure Support Agent (MISA), an agent of CoGTA*	GoGTA supports inter-governmental cooperation. MISA provides technical support to targeted municipalities, which will improve infrastructure planning, implementation, as well as operations and maintenance. MISA also manages deployment of professional service providers to municipalities, ensuring that sufficient technical capacity is built within municipalities, which will result in effective and efficient service delivery in the long term. This includes all training administration activities, and provision of comprehensive generic strategic support to the technical support and capacity development programmes.
	▶ *Department of Water and Sanitation (DWS);* ▶ *Catchment Management Agencies (CMAs)*	Must ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all persons; Must provide sector support with respect to water purification and treatment and wastewater treatment infrastructure operation and maintenance.
Land use and development planning	▶ *The Presidency*	The National Planning Commission was established to develop a long-term vision and strategic plan for South Africa. The main objective of the Commission is to rally the nation around a common set of objectives and priorities to drive development over the longer term. The Commission advises government on cross-cutting issues that influence the long-term development of South Africa.
	▶ *Department of Forestry, Fisheries and the Environment (DFFE); and* ▶ *Provincial departments of environmental affairs*	Are responsible for the implementation of the environmental management acts, including NEMA (107:1998) and the Environmental Management Framework (EMF) regulations that aim to ensure that environmental limits to development are included in spatial planning. EMFs attempt to achieve the desired developmental and ecological balance by utilizing early identification and mapping of sensitive ecosystems and resources to assist in pre-empting potential future land use conflicts. The EIA process provides an environmental instrument for local planning.
	▶ *Municipalities*	Municipalities are required to establish Integrated Development Plans (IDPs). An IDP is a plan for an area that gives an overall framework for development. It aims to co-ordinate the work of local, and other spheres of government, in a coherent plan to improve the quality of life for all the people living in that area. It considers the existing conditions and problems and resources available for development. It looks at economic and social development for the area as a whole. It is used by municipalities as a tool to plan short and long-term future development, including the water infrastructure.
	▶ *Department of Water and Sanitation (DWS);* ▶ *Water Management Institutions; and;* ▶ *Water Services Institutions*	To ensure that the country's water resources are protected, used, developed, conserved, managed and controlled by regulating and supporting the delivery of effective water supply and sanitation. The Water Services Development Plan (WSDP), as required by the WSA (108:1997), constitutes the water chapter of a municipality's IDP and deals with the long-term planning for the provision of water supply and sanitation services. Catchment Management Strategies, as required by the NWA (36:1998), deal with water resource management in WMAs. Catchment Management Strategies should influence development planning, and *vice versa*. Geographical water quality management strategies and thematic plans[373] provide content to Catchment Management Strategies and WSDPs

[373] Refer to **Section 3.1.2.4.6, Part 3**: Establishment of geographical water quality management strategies and thematic plans.

COMPETENCY[371]	RELEVANT AUTHORITY	ROLE IN THE MANAGEMENT OF EUTROPHICATION
Mining	▶ *Department of Mineral resources and Energy (DMRE)*	DMRE promotes mining. Is responsible for approving Environmental Management Programme Reports (EMPRs) and for the regulation and control of mining waste. In exercising this responsibility, DMRE is required to ensure that the DWS and CMAs are involved throughout the process of mine authorisation, and that no authorisation for mining is given without a water use authorisation from the DWS, which will include stringent water quality management conditions. Additionally, DMRE is also required to involve DWS and DFFE in the process of mine closure to effectively address the potential long-term water quality impacts of mines.
	▶ *Department of Water and Sanitation (DWS);* ▶ *Catchment Management Agencies (CMAs)*	Must ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all persons. Blasting and the mining of *"nutrients"*, such as phosphorus bearing rock, may contribute to excessive nutrient-loading of water resources and to anthropogenic eutrophication. The mine-water management policy should be implemented, and mine water regulation and authorisation processes must address relevant eutrophication-related issues. DWS and DFFE/ provincial departments of environmental affairs will develop a co-ordinated and joint water quality compliance monitoring and enforcement system to optimize the use of government resources and to achieve maximum impact.
	▶ *Department of Forestry, Fisheries and the Environment (DFFE); and* ▶ *Provincial departments of environmental affairs*	Are responsible for the implementation of the NEMA (107:1998) and for conducting EIAs for listed activities. The DFFE, in consultation with DWS and CMAs, must ensure that water quality impacts, including excessive nutrient-loading, are sufficiently dealt with in EIAs and through a co-ordinated compliance monitoring and enforcement approach.
Monitoring and evaluation	▶ *The Presidency*	The Department of Planning, Monitoring and Evaluation (DPME) must facilitate the implementation of the NDP through the development of sector specific and outcome-specific medium-term plans and delivery agreements, and monitor and evaluate the implementation of these plans; ensure the alignment of departmental strategic and annual plans and budget allocations with government's medium-term strategic framework; facilitate socio-economic impact assessments of legislation and regulations; monitor the performance of individual national and provincial government departments and municipalities, and related improvement plans, and facilitate targeted intervention programmes; monitor frontline service delivery; develop and implement the annual national evaluations plan and support the national evaluations system; and promote good planning, monitoring and evaluation practices in government.
	▶ *Department of Public Service and Administration (DPSA)*	To establish norms and standards to ensure that the state machinery functions optimally, and that such norms and standards are adhered to; implement interventions to maintain a compliant and functioning public service; promote an ethical public service through programmes, systems, frameworks and structures that detect, prevent and combat corruption; and contribute towards improved public administration. The DPSA is required to facilitate and support efforts that seek to, among others, improve service delivery quality and access; human resource management and development (Performance Management and Development System); business processes; systems and accountability management; anti-corruption and integrity; and effective public participation. Employee performance and corruption are aspects that relate to effective eutrophication management
	▶ *Department of Water and Sanitation (DWS)*	To ensure that the country's water resources are protected, used, developed, conserved, managed and controlled through oversight and supporting the delivery of effective water supply and sanitation. Establish monitoring systems for water resources and services with suitable and publicly available data and information.

COMPETENCY[371]	RELEVANT AUTHORITY	ROLE IN THE MANAGEMENT OF EUTROPHICATION
Research and development	▶ *Department of Water and Sanitation (DWS)*	The DWS, the DSI and the WRC are driving water research, development and innovation, nationally.
	▶ *Department of Science and Innovation (DSI);* ▶ *Technology Innovation Agency (TIA)*	The DSI, the DWS and the WRC are driving water research, development and innovation, nationally.
	▶ *Water Research Commission (WRC)*	The WRC, the DWS and the DSI are driving water research, development and innovation, nationally.
	▶ *Science councils, such as the Council for Scientific and Industrial Research (CSIR); the Agricultural Research Council (ARC); etc.*	Have catalytic roles in establishing a strong and diverse science, engineering and technology base for South Africa; Maintain a stable pool of internationally informed workers and allow for advanced human capacity development; Support the innovation continuum from discovery to application; and often find integrated solutions to complex problems or emerging research areas.
	▶ *South African National Biodiversity Institute (SANBI)*	Leads and coordinates research, and monitors and reports on the state of biological diversity in South Africa. The institute provides knowledge and information, gives planning and policy advice and pilots best-practice management models in partnership with stakeholders. Engages in ecosystem rehabilitation and restoration, leads the human capital development strategy of the biological diversity sector and manages the National Botanical and Zoological Gardens as 'windows' to South Africa's biological diversity for enjoyment and education.
Water and Sanitation	▶ *Department of Water and Sanitation (DWS)*	DWS is the apex department in relation to water quality management and will lead the co-ordination, alignment and implementation of policy, strategy and legislation that address aspects of eutrophication. DWS will establish the necessary institutional arrangements under the Inter-Governmental Relations Framework Act, 2005 (Act No. 13 of 2005) to ensure a government-wide approach to IWQM, including the management of eutrophication. DWS and DFFE/ Provincial departments of environmental affairs will develop a co-ordinated and joint water quality compliance monitoring and enforcement system to optimize the use of government resources and to achieve maximum impact.
	▶ *Catchment Management Agencies (CMAs) and proto-CMAs*	Are agencies of the DWS with delegated functions under the NWA (36:1998). As such, they must act in alignment with the NWRS2 and the IWQM Policy of the DWS, and must ensure that, at the catchment scale, effective co-ordination of planning and implementation takes place between the relevant government departments. In line with the principles of subsidiarity, the management of water quality (including eutrophication) will be delegated to CMAs, with the DWS providing the necessary oversight, national strategic guidance, and control of transboundary matters. The CMAs will also build the necessary capacity to act under Section 19(3) to (6) of the NWA (36:1998), which is a responsibility allocated to them by the NWA (36:1998). The Catchment Management Committees, Catchment Management Forums (CMF) and other Water Management Institutions will be used, as appropriate, to manage or control eutrophication.

COMPETENCY[371]	RELEVANT AUTHORITY	ROLE IN THE MANAGEMENT OF EUTROPHICATION
	▶ *Department of Forestry, Fisheries and the Environment (DFFE); and* ▶ *Provincial departments of environmental affairs*	Are responsible for the implementation of the NEMA (107:1998) and for conducting EIAs on development projects. The DFFE must ensure, in consultation with DWS and CMAs, that water quality impacts, including excessive nutrient-loading, are sufficiently dealt with in EIAs and through a co-ordinated approach with the DWS to ensure compliance monitoring and enforcement. Waste is administered and managed under the National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008)[374] and should not cause nutrient-loading of water resources.
	▶ *Department of Cooperative Governance and Traditional Affairs (CoGTA)*	Must improve cooperative governance across the three spheres of government, in partnership with institutions of traditional leadership, to ensure that provinces and municipalities carry out their service delivery and development functions effectively. CoGTA, *inter alia*, publishes information on municipal support and assists through capacity-building programmes.
	▶ *South African Local Government Association (SALGA)*	SALGA is the constitutionally mandated organisation responsible for local government oversight. As protector, SALGA robustly enforces the rights of the local government sector.
	▶ *Municipalities*	Municipalities have a regulatory role in relation to ensuring that by-laws regarding solid waste management and stormwater management systems reduce water pollution from municipal areas. In this regard, they carry part of government's responsibilities for preventing and reducing water pollution, and must ensure that management and control of such forms of diffuse water pollution are clearly addressed in their WSDPs. At the same time, municipalities are responsible for sanitation provision and WwTWs, which are critical in improving the trophic conditions in water resources. In this regard, the DWS, working with the national and provincial departments of cooperative government, has a regulatory role to ensure that WwTWs are duly licensed under the NWA (36:1998), that Municipalities ensure that their WwTWs meet WDSs, and to take action to ensure compliance by municipalities. In this regard, the DWS will implement its internal protocol on engagement with municipalities, including taking legal action where necessary.
	▶ *Department of Finance; and* ▶ *National Treasury (NT)*	To promote government's fiscal policy framework; Coordinate macroeconomic policy and intergovernmental financial relations; Manage the budget preparation process; Facilitate the Division of Revenue Act, 2013 (Act No. 2 of 2013) which provides for an equitable distribution of nationally raised revenue between national, provincial and local government; and monitor the implementation of provincial budgets. Financial resources are important and are needed to manage eutrophication. Involving NT officials at important stages of managing eutrophication will ensure a better understanding of challenges and needs, and *vice versa*.

[374] Hereafter referred to as NEMWA (59:2008).

CHAPTER 6: CONCLUSION

Part 3 presented a comprehensive *"framework"* for the management of eutrophication in South Africa. This *"framework"* was developed in the form of a strategy, which specifies authority (***"who?"***), prescribed approach and action (***"what and how?"***), and spatial (***"where?"***) and temporal (***"when?"***) scales of implementation. The strategy, further, was structured into three types of interrelated and mutually supporting strategies; these being–

- Core strategies;
- Operational strategies; and
- Supporting strategies, for eutrophication management.

The **Core Strategies** focus on the *"three faces"* or characters of eutrophication management, namely **Source** Directed, **Resource** Directed and **Remediation** Directed Management, and highlight the linkages between these strategies. The focus of the **Operational Strategies** is on the operational management of eutrophication, and strategic guidance on multiple operational aspects of eutrophication management were included by packaging them into an internationally accepted framework, known as the *"**P**lan-**D**o-**C**heck-**A**ct"* or P-D-C-A cycle [Moen & Norman, 2009]. The **Supporting Strategies**, lastly, focus on strategic measures that support eutrophication management, and strategies for *"Technical capacity building to give impetus to eutrophication management"*; *"Research and technology development to address eutrophication-related challenges"*; and *"Collaboration and management participation"* were developed. The outlines of all these strategies and their components overlap, and necessitates an integrated and comprehensive approach towards addressing anthropogenic eutrophication effectively in South Africa. Importantly, the implementation of measures to manage eutrophication needs to take place in a holistic and cooperative manner, being cognisant of the requirements of integrated water quality management.

Part 3 concludes with a focussed discussion on *"governance"* that revolve around a summation of competencies, relevant authorities and potential roles being played by them in the management of eutrophication.

A one-page table, in **Annexure J**, provides a quick reference to the Eutrophication Management Strategy, for later use.

A total of 110 short-term and longer-term strategic actions were collectively identified to strengthen eutrophication management (**TABLE 37**). These actions need to be considered, prioritised and incorporated in an implementation plan to convert strategy into action.

TABLE 37: Number of strategic actions that was identified to strengthen eutrophication management.

EUTROPHICATION MANAGEMENT STRATEGIES	NUMER OF STRATEGIC ACTIONS
CORE STRATEGIES	
Source Directed Management	7
Resource Directed Management	4
Remediation Directed Management	8
Sub-total	***19***
OPERATIONAL STRATEGIES	
Plan stage	6
Do stage	22
Check stage	21
Act stage	12
Sub-total	***61***
SUPPORTING STRATEGIES	
Technical capacity building	9
Research and technology development	13
Collaboration and management participation	8
Sub-total	***30***
TOTAL	**110**

Implementation, now, is in the hands of those that are responsible for roll-out and implementation. A good strategy on the shelf is worth little without willingness to implement it. Knowledge, policy and strategy, now, need to be converted into concrete action that improves the lives of water users and of every South African!

Part 4

THE WAY FORWARD

PART 4: THE WAY FORWARD

PHOTO 4: ***"ACTION IS THE KEY TO SUCCESS!"***

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CHAPTER 1: INTRODUCTION

Although, generally regarded as a developing country, South Africa has some elements in common with first world countries, amongst others, its world-class water policies and legislation. Yet, implementation, in many respects, remains challenging for reasons such as diminishing sector capacity, competence and leadership; lack of training, collaboration, and effective coordination amongst responsible authorities and implementing agencies; slow progress with the establishment of Water Management Institutions[154], especially CMAs [Nepfumbada & Seetal, 2020], Catchment Management Strategy establishment, and the realisation of the full ambition of catchment[21] management; as well as regulatory action that does not necessarily convert into improved resource water quality[156], to name but a few. Many of these reasons constitute risk factors that are outside of the scope of the Eutrophication Management Strategy for South Africa. It is essential that all these challenges, within and outside of the scope of the Strategy, must receive appropriate attention. This is only possible through effective leadership, coordination, collaboration, management participation and ACTION.

CHAPTER 2: IMPLEMENTATION

The umbrella IWQM Vision and Mission were adopted for the management of eutrophication[58] in South Africa. In addition, thereto, a national goal for eutrophication management, namely: ***"To manage eutrophication effectively in order to protect aquatic ecosystems and to secure water resources that are fit-for-use."***, and a number of concomitant objectives, were also adopted. Collectively, this suite of aspirational goals established a visionary and resolute guiding thrust for the newly developed eutrophication management policy and strategy.

The Eutrophication Management Policy contains fourteen policy statements, which are more of a technical nature, and five supporting policy statements, which are more of a general and crosscutting nature. Together they are regarded as most pertinent to eutrophication management in South Africa. The Eutrophication Management Strategy, further, provides strategic guidance to policy implementation. Although the Strategy lends itself to implementation by specifying authority (***"who?"***), prescribing approach and action (***"what and how?"***), and pointing to spatial (***"where?"***) and temporal (***"when?"***) scales of implementation, strategy implementation, now, needs to be scheduled with concrete deadlines, and resourced in terms of human capital, budget and equipment, as necessary.

The development of an Implementation Plan to convert strategy into practice (Project Report No. 6: Converting Strategy into Practice Report), provides an opportunity to articulate, in a structured way, how the Eutrophication Management Policy and Strategy can be pragmatically implemented. In effect, the Implementation Plan becomes the critical catalyst for shifts in approach towards achievement and full roll-out. Core considerations [DWS, 2017d] for the formulation of the Implementation Plan include:

- **A short to medium-term focus, in the context of longer-term aspirations for eutrophication management:**

  The NWA (36:1998) enables the NWRS to be developed progressively over time, with a mandatory requirement to be reviewed and updated regularly within a 5-year frequency. This translates into the NWRS having a long-term vision, which is supported by short to medium term actions. It also enables the NWRS to be improved and updated more regularly, as required, in order to be adaptive.

  The Eutrophication Management Strategy, potentially as part of the NWRS, must focus on those actions that are regarded as critical and which are prioritised for short to medium-term implementation, whilst also considering the longer-term requirements and actions that collectively must realise the Eutrophication Management Goal. The Implementation Plan needs to be pragmatic in giving effect to the Eutrophication Management Strategy in a clear, concise and measurable manner.

- **Prioritising critical concerns for action, while ensuring that other issues are addressed through on-going management or monitoring for future prioritisation and action:**

  It is not possible to address all the many eutrophication-related challenges simultaneously. The availability of human and financial resources, as well as information and systems constraints, will inhibit this. Therefore, the focus of the Implementation Plan must be on delivering change for prioritised challenges first. This does not mean that work on other areas, pertinent to the management of eutrophication, will not continue, but it serves to guide the allocation of human and financial resources.

- **Relevance at transboundary, national, catchment, local and source specific scales, while ensuring alignment, at each spatial scale, across sectors:**

  The Eutrophication Management Strategy has to have vertical relevance between different spatial scales, *i.e.,* the transboundary, national, catchment, local and source specific scales, whilst also addressing issues horizontally at each spatial scale that are specific to certain sectors, or between sectors. These vertical and horizontal interfaces present an array of institutional and administrative challenges that are not easy to overcome, but that are critical to ensure the effective management of eutrophication.

Whilst the roles of different departments and organisations vary according to spatial scale and mandate, the catchment level is understood as the critical scale for managing eutrophication. It is the various interfaces at the catchment scale that are key to successful management of water quality, and specifically of eutrophication. Therefore, the role of CMAs becomes an important facilitator to this end, and the development of catchment management strategies, becomes a key instrument to guide the strategic and adaptive management of excessive nutrient-loading and anthropogenic eutrophication. As such, the Implementation Plan needs to prioritise catchment level interventions.

- **The inclusion of measurable targets for regular monitoring and evaluation:**

Noting the complexities associated with managing eutrophication, which *inter alia* involves dimensions of water resource protection, planning, land and water use authorisation, regulation, monitoring and oversight, it is important to provide a purposeful and pragmatic framework that enables short and medium-term achievement towards a longer-term purpose. In this regard, the Implementation Plan must have a short to medium-term implementation focus and review cycle, which support the use of Annual Performance Plans (APPs) (including operational planning and employee Performance Agreements) in government. Of critical importance is the development and inclusion of SMART (Specific, Measurable, Agreed-upon, Realistic, Time-based) targets in the Implementation Plan.

- **Adaptive responses, enabled by effective on-going monitoring and evaluation:**

The management of complex socio-economic and ecological systems requires an adaptive management approach. Successful implementation of the Eutrophication Management Strategy will be based on the ability of government (particularly at catchment scale) to implement a deliberate, systems-based, adaptive management approach. This approach must be inclusive, bringing together on a regular basis government, private sector and civil society role-players to review and adapt approaches and actions.

Adaptive management enables the refinement of those actions that must be taken. This includes the refocusing of financial and human resource allocation, once certain actions have been implemented or certain milestones achieved. When the expected results from implemented actions are not achieved, or when new information becomes available, which informs improved approaches, adaptions must be made for future implementation.

The Implementation Plan should support this approach through an effective monitoring and evaluation system. This needs to take place at the catchment scale where the most substantial implementation of the Eutrophication Management Strategy will take place. This system needs to be structured around a broader programmatic monitoring and evaluation approach, which would include a reflection of impacts upon the trophic status[145] of significant water resources.

CHAPTER 3: CONCLUSION

A comprehensive framework specifying both intent and strategic approach for management of eutrophication-related causes and effects exists now and must be implemented!

An evaluation of current legislation showed that many provisions exist and can potentially be utilised for improved eutrophication management but have not yet been employed or fully implemented since the promulgation of the NWA (36:1998). In the short term, all provisions in the NWA (36:1998), and in other acts must be considered for urgent implementation. In this regard, reference to the full roll-out of the WDCS, various regulations that can be made under Section 26 of the NWA (36:1998) and statutory RDMs - through an appropriate water use authorisation process, are noted. Old WDSs, especially the uniform phosphorus[107] standard of 1 mg/ℓ orthophosphate dating back to 1984, must be evaluated and revised. Improved regulation and the operationalising of the Receiving Water Quality Objectives Approach[119], already adopted in 1991 and made possible by the NWA (36:1998), must receive priority attention. Additionally, CMAs must be established for all WMAs, and CMAs, or proto-CMAs in the absence of CMAs, must be empowered to accelerate catchment eutrophication management.

In addition to point source control, the effective management of excessive diffuse[38] nutrient-loading probably presents a significant opportunity to improve the trophic status of many receiving water resources. Many innovative and improved approaches were included. Some of these approaches include: exploring and developing ways to ensure appropriate remediation[121] of legacy cases; elevating the roles to be played by planning for water quality to a level matching the level of planning for water demand and supply; the development of methodologies for waste load accounting and the determination of NLOs; the development of an appropriate suite of BMPs and BMGs; revitalising and expanding Green Drop certification to certification schemes that potentially also includes other important water use sectors; the introduction of a LCA approach, as well as the potential use of certification schemes with public information to show the suitability of products from a water resource perspective, to name but a few.

As the sector leader, the DWS understands that the management of water resources and services requires a sector-wide approach, and that this is a central theme in the implementation of the NWRS. Similarly, the management of eutrophication requires a broader engagement that moves roles and relationships beyond that of the water user, stakeholder, policymaker and regulator, towards one of cooperation, partnership and stewardship. Sustainable water resource use cannot be ensured by the DWS without the buy-in and support of the broader sector. Noting that different government departments and sectors have quite different interfaces with water resources, there is a need for a differentiated approach to this mobilisation of the broader water sector. This differentiated approach will need to be outlined further in the Implementation Plan - in support of the Eutrophication Management Strategy. The leading role of DWS in developing and maintaining these relationships will be critical.

The development of an Implementation Plan for strategy roll-out (Project Report No. 6: Converting Strategy into Practice Report) constitutes the next step towards full implementation. This document, *i.e.,* the Eutrophication Management Strategy for South Africa, provides a solid foundation upon which to build, especially the actions listed in the *"strategic action"*, *"operational action"* and *"supporting action"* tables throughout Part 3 under *"temporal scales of implementation"*. As such, **TABLE 14**, **TABLE 15**, **TABLE 16**, **TABLE 18**, **TABLE 22**, **TABLE 29**, **TABLE 31**, **TABLE 32**, **TABLE 33** and **TABLE 35** should be transferred to (and expanded in) Implementation Plan(s) to be scheduled more definitively for implementation and for resourcing purposes. Monitoring and evaluation of Implementation Plan(s) will be undertaken by the DWS. Successful implementation towards protecting aquatic ecosystems and securing water resources that are fit for use, ultimately depends on the appropriate resourcing of strategy implementation, effective stakeholder participation and the will to improve the trophic conditions of water resources.

Even though the Eutrophication Management Strategy for South Africa is regarded as a stable document that is ready for implementation currently, its revision in the future is inevitable (and is advisable) to keep pace with changing circumstances and priorities. Additionally, in the future it can be considered jointly with the DFFE to expand its scope to also include the management of eutrophication in coastal marine waters too. The *Eutrophication Management Strategy for South Africa* can possibly be expanded, or alternatively be split into two separate, but linked strategies, towards fully addressing all anthropogenic eutrophication in both inland and coastal marine waters.

BIBLIOGRAPHY

Part 5

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LEGISLATION REFERENCES

GN R.553 in GG 217 of 5 April 1962. **Regional Standards for Industrial Effluents**.

GN R.1567 in GG 7159 of 1 August 1980. **Amendment of Standard for Industrial Wastewater and Effluent in Terms of Section 21(1)(a) of the Water Act, 1956**.

GN R.991 in GG 9225 of 18 May 1984. **Requirements for the Purification of Wastewater or Effluent.**

GN R.2834 in GG 10088 of 7 February 1986. **Regulations in terms of Section 26 read in conjunction with Section 12A of the Water Act, 1956 (Act No. 54 of 1956), for the erection, enlargement, operation and registration of water care works.**

GN R704 in GG 20119 of 4 June 1999: **Regulations on the use of water for mining and related activities aimed at the protection of water resources.** Regulations made in terms of Section 26(1)(b), (g) and (i) of the National Water Act, 1998 (Act No. 36 of 1998).

GN R.509 in GG 22355 of 8 June 2001. **Regulations relating to compulsory national standards and measures to conserve water.** Regulations made in terms of Sections 9(1) and 73(1)(j) of the Water Services Act, 1997 (Act No. 108 of 1997).

GN R.180 in GG 28557 of 24 February 2006. **Draft regulations regarding the registration of waterworks and process controllers in terms of Section 116 of the National Water Act, 1998 (Act No. 36 of 1998)**.

GN R.1188 in GG 29413 of 1 December 2006. **Draft regulations for the use of water for recreational purposes, generally and in respect of a government waterworks and surrounding state-owned land**. Regulations made in terms of Sections 26(1)(a) and (g) of the National Water Act, 1998 (Act No. 36 of 1998)

GN R.813 in GG 36958 of 23 October 2013. **Draft regulations relating to Compulsory National Standards for Process Controllers and Water Services Works.** Regulations made in terms of Sections 9(1) of the Water Services Act, 1997 (Act No. 108 of 1997).

GN R.1388 in GG 41310 of 8 December 2017. **Proposed Classes of water resource and Resource Quality Objectives for Mokolo, Matlabas, Crocodile (West) and Marico Catchments.**

(RSA). 1996, **Constitution of the Republic of South Africa, 1996 (Act No. 108 of 1996)**. PRETORIA: Government Printers, Republic of South Africa (RSA).

RSA. 1997, **Water Services Act, 1997 (Act No.108 of 1997)**. PRETORIA: Government Printers, Republic of South Africa (RSA).

RSA. 1998, **National Environmental Management Act, 1998 (Act No. 107 of 1998)**. PRETORIA: Government Printers, Republic of South Africa (RSA).

RSA. 1998, **National Water Act, 1998 (Act No. 36 of 1998)**. PRETORIA: Government Printers, Republic of South Africa (RSA).

LITERATURE REFERENCES

Algotsson, E., Murombo, T., Davis, M. & Poole, M., 2009. *Water Supply and Sanitation in South Africa - Environmental Rights and Municipal Accountability,* PRETORIA: Lawyers for Human Rights.

Allanson, B. R. & Gieskes, J., 1961. An introduction to the limnology of Hartbeespoort Dam with special reference to the effect of industrial and domestic pollution - Part II of Investigations into the ecology of polluted inland waters in the Transvaal. *Hydrobiologia,* 18[(1–2)], p. 77–94.

Arnold, R. D. & Wade, J. P., 2015. A definition of systems thinking: A systems approach. *Procedia Computer Science,* Volume 44, pp. 669-678.

Ashton, P. J. et al., 1985. Limnology of Hartbeespoort Dam. *National Scientific Programmes Report,* Issue No. 110, p. 267.

Atlas, R. M. & Bartha, R., 1987. *Microbial Ecology: Fundamentals and Applications.* 2 ed. MENLO PARK, CA: Benjamin Cummings Publishing Company Inc..

Baron, J. S. & Poff, L. N., 2004. Sustaining Healthy Freshwater Ecosystems. *Water Resources Update,* Issue 127, pp. 52-58.

Beechie, T. & Bolton, S., 1999. Approach to restoring salmonid habitat-forming processes in Pacific Northwest watersheds. *Fisheries,* 24[4], pp. 6-15.

Bennekom, A. J. & Van Salomons, W., 1981. *Pathways of nutrients and organic matter from land through rivers. SCOR Working Group No. 46, Precedures of Review Workshop: River Inputs to Ocean Systems.* NEW YORK, United Nations (UN), pp. 33-51.

Blomqvist, S., Gunnars, A. & Elmgren, R., 2004. Why the limiting nutrient differs between temperate coastal seas and freshwater lakes: A matter of salt. *American Society of Limnology and Oceanography,* 96[6], p. 2236–2241.

Breen, C. M., Jaganyi, J. J., Van Wilgen, B. W. & Van Wyk, E., 2004. Research projects and capacity building. *Water SA,* 30[4], pp. 1-6.

Brock, T. D. & Madigan, M. T., 1988. *Biology of Microorganisms.* 5 ed. EAGLEWOOD CLIFFS, NJ: Prentice-Hall International Editions.

Brundtland, G., 1987. *Report of the World Commission on Environment and Development: Our Common Future,* s.l.: United Nations General Assembly document A/42/427.

Carlson, R. E., 1977. A Trophic State Index for Lakes. *Limnology and Oceanography,* p. 361.

Carlson, R. E. & Simpson, J., 1996. *Defining Trophic State - An extract from A Coordinator's Guide to Volunteer Lake Monitoring,* MADISON, WI: Lake Standard Sub-Committee, North American Lake Management Society.

Chamier, J. et al., 2012. Impacts of invasive alien plants on water quality, with particular emphasis on South Africa. *Water SA,* 38[2], pp. 345-356.

Cholnoky, B. J., 1958. Hydrobiologische untersuchungen in Transvaal II. Selbstreinigung im Jukskei-Crocodile Flusssystem.. *Hydrobiologia, 11 (3–4), 205–266.,* 11[3–4], p. 205–266.

Clark, C. M. et al., 2017. Nitrogen-induced terrestrial eutrophication: cascading effects and impacts on ecosystem services. *Ecosphere,* Volume 8[7], pp. 1-28.

Colvin, C. et al., 2013. *An Introduction to South Africa's Water Source Areas,* CAPE TOWN: World Wildlife Fund (WWF) - South Africa.

Cook, S. C., Housley, L., Back, J. A. & King, R. S., 2018. Freshwater eutrophication drives sharp reductions in temporal beta diversity. *Ecology,* Volume 99[1], pp. 47-56.

Correll, D. L., 1998. The role of phosphorus in the eutrophication of receiving waters: A review. *Journal of Environmental Quality,* Volume 27, pp. 261-266.

Costanza, R. et al., 1997. The value of the world's ecosystem services and natural capital. *Nature,* Volume 387, pp. 253-260.

Craig, E. W. et al., 2014. Solar ultraviolet radiation in a changing climate. *Nature Climate Change,* Volume Volume 4, pp. 434-441.

Davis, B. D., Dulbecco, R., Eisen, H. N. & Ginsberg, H. S., 1980. *Microbiology.* 3 ed. PHILADELPHIA, PA: Harper International Edition.

Davis, J. R. & Koop, K., 2001. *Current understanding of the eutrophication process in Australia (IAHS Publication no. 268).* MAASTRICHT, Regional Management of Water Resources (Proceedings of a symposium held during the Sixth IAHS Scientific Assembly, pp. 89-95.

Davis, J. R. & Koop, K., 2006. Eutrophication in Australian rivers, reservoirs and estuaries – a southern hemisphere perspective on the science and its implications. *Hydrobiologia,* Volume 559, pp. 23-76.

Davis, L., 1995. *A Handbook of Constructed Wetlands - A Guide to creating wetlands for agricultural wastewater, domestic wastewater, coal mine drainage and stormwater in the Mid-Atlantic Region. (Volume 1: General Considerations),* Washinton DC: United States Environmental Protection Agency (US EPA) Region III.

De Beer, B. K., 1975. *Agter die Magalies.* s.l.:Postma Publikasies.

DEA, 2014. *National Guideline for the Discharge of Effluent from Land-based Sources into the Coastal Environment,* PRETORIA: Deapartment of Environmental Affairs (DEA).

DEFF, 2018. *Overall Policy on Environmental Offsetting in South Africa - Final draft for public comment,* PRETORIA: Department of Environment, Forestry and Fisheries (DEFF).

Diaz, R. J. & Rosenburg, R., 2008. Spreading Dead Zones and Consequences for Marine Ecosystems. *Science,* 15 August, 321[5891], pp. 926-929.

DPSA, 1997. *White Paper on Transforming Public Service Delivery.* Government Gazette No. 18340; Vol 388; Government Notice 1459 ed. PRETORIA: Department of Public Service and Administration (DPSA).

DPSA, 2007. *Employee Performance Management and Development System,* PRETORIA: Department of Public Service and Administration (DPSA).

DST, 2015. *National Water Research, Development and Innovation (RDI) Roadmap,* PRETORIA: Department of Science and Technology (DST) and Water Research Commission (WRC).

Dunst, R. C. et al., 1974. Survey of lake rehabilitation techniques and experiences. *Technical Bulletin (Wisconsin Department of Natural Resources),* Volume 75, p. 179 pp.

DWA, 1986. *Management of the Water Resources of the Republic of South Africa,* PRETORIA: Department of Water Affairs (DWA).

DWA, 2010. *Integrated Water Resource Planning for South Africa. Report No. P RSA 000/00/12910,* PRETORIA: Department of Water Affairs (DWA).

DWA, 2011a. *National Strategy for Water Reuse - National Water Resource Strategy (Annexure D),* PRETORIA: Department of Water Affairs (DWA).

DWA, 2011b. *Planning Level Review of Water Quality in South Africa. WRPS Sub-Series No. WQP 2.0,* PRETORIA: Department of Water Affairs (DWA).

DWA, 2013. *Green Drop Report executive summary,* PRETORIA: Department of Water Affairs (DWA).

DWAF, 1991. *Water Quality Management Policies and Strategies in the RSA,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

DWAF, 1995. *Procedures to Assess Effluent Discharge Impacts - Report No. TT 64/94,* PRETORIA: Department of Water Affairs and Forestry (DWAF) & Water Research Commission (WRC).

DWAF, 1996. *South African Water Quality Guidelines (Volumes 1 to 8).* 2 ed. PRETORIA: Department of Water Affairs and Forestry (DWAF).

DWAF, 1997. *White Paper on a National Water Policy for South Africa,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

DWAF, 2000. *Policy and Strategy for Groundwater Quality Management in South Africa (First Edition). Report No. W.1.0,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

DWAF, 2002. *National Eutrophication Monitoring Programme – Implementation Manual,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

DWAF, 2003a. *A Guide to conduct Water Quality Catchment Assessment Studies: In support of the Water Quality Management Component of a Catchment Management Strategy (Edition 1). WQM Series, Sub-Series No. 8.3,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

DWAF, 2003b. *A Guideline to the Water Quality Management component of a Catchment Management Strategy (Edition 1). WQM Series, Sub-Series No. 8.2,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

DWAF, 2004. *Operational Policy for the Disposal of Land-derived Water Containing Waste to the Marine Environment of South Africa,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

DWAF, 2006a. *Resource Directed Management of Water Quality (Appendix C): Guidelines for Setting Licence Conditions for Resource Directed Management of Water Quality (Edition 1). WRPS Series, Sub-Series No. WQP 1.7.5,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

DWAF, 2006b. *Resource Directed Management of Water Quality (Volume 1.2): Policy (Edition 1). WRPS Series, Sub-Series No. WQP 1.4.2,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

DWAF, 2006c. *Resource Directed Management of Water Quality (Volume 4.1): Guideline for Catchment Visioning for the Resource Directed Management of Water Quality (Edition 2). WRPS Series, Sub-Series No. WQP 1.6.2,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

DWAF, 2006d. *Resource Directed Management of Water Quality (Volume 4.2): Guideline for determining Resource Water Quality Objectives (RWQOs), Allocatable Water Quality and the Stress of the water resource (Edition 2). WRPS Series, Sub-Series No. WQP 1.7.2,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

DWAF, 2006e. *Resource Directed Management of Water Quality (Volume 4.3): Guideline on Monitoring and Auditing for Resource Directed Management of Water Quality (Edition 2). WRPS Series, Sub-Series No. WQP 1.7.3,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

DWAF, 2006f. *Resource Directed Management of Water Quality (Volume 3): Institutional Arrangements (Edition 1). WRPS Series, Sub-Series No. WQP 1.5.3,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

DWAF, 2008. *Water for growth and development strategy: Draft Discussion Document,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

DWS, 2013. *National Water Resource Strategy - Edition 2,* PRETORIA: Department of Water Affairs (DWA).

DWS, 2014. *Green Drop Progress Report,* PRETORIA: Department of Water and Sanitation (DWS).

DWS, 2015a. *Climate Change: National Climate Change Response Strategy for the Water Sector,* PRETORIA: Department of Water and Sanitation (DWS).

DWS, 2015b. *Planning Level Review of the Water Quality in South Africa. A Situation Analysis (Draft). Water Resource Planning Systems: Water Quality Planning.* PRETORIA, Department of Water and Sanitation (DWS).

DWS, 2016a. *Integrated Water Quality Management Policies and Strategies for South Africa: Integrated Water Quality Management Organisational Design Recommendations - Edition 1 (Report No. 4.4) (Water Resource Planning Systems Series No. 000/00/21715/21,* PRETORIA: Department of Water and Sanitation (DWS).

DWS, 2016b. *Review, Evaluation and Optimisation of the South African Water Resources Monitoring Network,* PRETORIA: Department of Water and Sanitation (DWS).

DWS, 2017a. *Integrated Water Quality Management Policies and Strategies for South Africa: Water Quality and Water Quality Management challenges in South Africa (Report No. 1.3) (Water Resource Planning Systems Series Report No. 000/00/21715/5,* PRETORIA: Department of Water and Sanitation (DWS).

DWS, 2017b. *Integrated Water Quality Management Policies and Strategies for South Africa: Policy – Edition 2 (Report No. 2.2) (Water Resource Planning Systems Series Report No. 000/00/21715/13,* PRETORIA: Department of Water and Sanitation (DWS).

DWS, 2017c. *Integrated Water Quality Management Policies and Strategies for South Africa: Policy Summary – Edition 2 (Report No. 2.3) (Water Resource Planning Systems Series Report No. 000/00/21715/14).,* PRETORIA: Department of Water and Sanitation (DWS).

DWS, 2017d. *Integrated Water Quality Management Policies and Strategies for South Africa: Strategy – Edition 2 (Report No. 3.2) (Water Resource Planning Systems Series Report No. 000/00/21715/13,* PRETORIA: Department of Water and Sanitation (DWS).

DWS, 2017e. *Integrated Water Quality Management Policies and Strategies for South Africa: Strategy Summary – Edition 2. (Report No. 3.3) (Water Resource Planning Systems Series Report No. 000/00/21715/17),* PRETORIA: Department of Water and Sanitation (DWS).

DWS, 2017f. *Integrated Water Quality Management Policies and Strategies for South Africa: Implementation Plan – Edition 2 (Report No. 4.2) (Water Resource Planning Systems Series Report No. 000/00/21715/19),* PRETORIA: Department of Water and Sanitation (DWS).

DWS, 2017g. *Integrated Water Quality Management Policies and Strategies for South Africa: Monitoring and Evaluation Framework – Edition 1 (Report No. 4.3) (Water Resource Planning Systems Series Report No. 00/00/21715/20),* PRETORIA: Department of Water and Sanitation (DWS).

DWS, 2018a. *National Water and Sanitation Master Plan – Volume 1: Call to Action (Version 10.1),* PRETORIA: Department of Water and Sanitation (DWS).

DWS, 2018b. *National Water and Sanitation Master Plan – Volume 2: Plan to Action (Version 4.2),* PRETORIA: Department of Water and Sanitation (DWS).

DWS, 2018c. *National Water and Sanitation Master Plan – Volume 3: Schedule of Action (Version 4.8),* PRETORIA: Department of Water and Sanitation (DWS).

DWS, 2020. *Data Management Strategy for Water and Sanitation in South Africa (Edition 1),* PRETORIA: Department of Water and Sanitation (DWS).

DWS, 2021. *National Water Resource Strategy - Edition 3 (Draft 2.6),* PRETORIA: Department of Water and Sanitation (DWS).

DWS, 2022. *Green Drop National Report.* PRETORIA: Department of Water and Sanitation (DWS).

Egge, J. K. & Aksnes, D. L., 1992. Silicate as Regulating Nutrient in Phytoplankton Competition. *Marine Ecology Progress Series,* Volume 83, pp. 281-289.

EPA, 2000a. *Nutrient Criteria Technical Guidance Manual: Rivers and Streams (EPA-822-B-00-002),* WASHINGTON, DC: United States Environmental Protection Agency (EPA).

EPA, 2000b. *Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs, First Edition (EPA-822-B00-001),* WASHINGTON, DC: United States Environmental Protection Agency (EPA).

EPA, 2001. *Nutrient Criteria Technical Guidance Manual: Estuarine and Coastal Marine Waters (EPA-822-B-01-003),* WASHINGTON, DC: United States Environmental Protection Agency (EPA).

EPA, 2008. *Nutrient Criteria Technical Guidance Manual: Wetlands (EPA-822-B-08-001),* WASHINGTON DC: United States Environmental Protection Agency (EPA).

EU & WHO, 2002. *Eutrophication and health,* LUXEMBOURGH: European Commission (EU) and World Health Organization (WHO).

Fosberg, C. & Ryding, S. O., 1980. Eutrophication parameters and trophic state indices in 30 Swedish waste-receiving lakes. *Arch. Hydrobiol.,* Volume 89, pp. 189-207.

Frost & Sullivan, 2010. *Eutrophication Research Impact Assessment. WRC Report No. TT 461/10,* PRETORIA: Water Research Commission (WRC).

Garvin, S. M. & Enck, J. A., 2010. *Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment,* Washington DC: United States (UN) Environmental Protection Agency (EPA).

George, G., Hurley, M. & Hewitt, D., 2007. The impact of climate change on the physical characteristics of the larger lakes in the English Lake District. *Freshwater Biology,* Volume 52 [9], pp. 1647-1666.

Glazewski, J., 2005. *Environmental law in South Africa, Second Edition,* DURBAN: Lexis NexisButterworths.

Graham, M. & Taylor, J., 2018. *Development of citizen science water resource monitoring tools and communities of practice for South Africa, Africa and the world,* PRETORIA: Water Research Commission (WRC).

Grobler, D. C. & Silberbauer, M. J., 1985. Eutrophication control: A look into the future. *Water SA,* 11[2], pp. 69-78.

Grobler, G., 2012. *Water quality monitoring* [Interview] [28 3 2012].

Guinee, J. B. et al., 2011. Life Cycle Assessment: Past, Present, and Future. *Environmental Science and Technology,* 45[1], pp. 90-96.

Hancock, W. K., 1962. *Smuts: The Sanguine Years (1870-1919).* s.l.:Cambridge University Press.

Harding, W. R., 2008. *The Determination of Annual Phosphorus Loading Limits for South African Dams,* PRETORIA: Water Research Commission (WRC).

Harding, W. R., 2015. Living with Eutrophication in South Africa: A review of realities and challenges. In: *Transactions of the Royal Society of South Africa.* 70:2 ed. s.l.:Published online, pp. 155-171.

Harding, W. R., 2017. *The threat to South African water security posed by wastewater-driven eutrophication: A proposal for a new regulatory approach.* Research dissertation ed. CAPE TOWN: School for Advanced Legal Studies, University of Cape Town.

Harding, W. R., 2022. *Eutrophication* [Interview] [August 2022].

Harding, W. R. & Hart, R. C., 2013. Food-web structure in the hypertrophic Rietvlei Dam based on stable isotope analysis: Specific and general implications for reservoir biomanipulation. *Water SA,* 39[5].

Harper, D., 1992. *Eutrophication of Freshwaters: Principles, Problems and Restoration.* Leicester: Springer, Dordrecht.

Havlíček, F. & Morcinek, M., 2016. Waste and Pollution in the Ancient Roman Empire. *Journal of Landscape Ecology,* 9[2], pp. 33-49.

Holdren, C., Jones, W. & Taggert, J., 2001. *Managing Lakes and Reservoirs,* MADISON, WI: North American Lake Management Society and Terrene Institute, in cooperation with the Office of Water Assessment, Watershed Protection Division, USEPA.

Howman, A., Grobler, D., Kempster, P. & Seed, A., 1989. LANDSAT and limnologically derived water quality data: A perspective. *Environmental Monitoring and Assessment,* 13[1], pp. 1-9.

Howman, A. M. & Kempster, P. L., 1986. *Landsat water quality surveillance model CALMCAT, Technical Report No. TR 128,* PRETORIA: Department of Water Affairs (DWA): Hydrological Research Institute (HRI).

ISO, 2006. *ISO 14044, Environmentyal Management - Life Cycle Assessment - Requirements and guidelines.* GENEVA: South African Bureau of Standards (SABS).

ISO, 2015. *Environmental management systems - Requirements with guidance for use.* GENEVA: South African Bureau of Standards (SABS).

Jepson, W. et al., 2017. Advancing human capabilities for water security: A relational approach. *Water Security,* Volume 1.

JICA Task Force on aid approaches, 2004. *Capacity Development Handbook for JICA staff.* s.l.:JICA.

Kristensen, P., 2004. *The DPSIR Framework, Paper presented at the 27-29 September 2004 workshop on a comprehensive/ detailed assessment of the vulnerability of water resources to environmental change in Africa using a river basin approach.* UNEP Headquarters, Nairobi, Kenya, Department of Policy Analysis, European Topic Centre on Water, European Environment Agency (EEA), p. 10.

le Maitre, D. et al., 2018. *Strategic Water Source Areas: Management Framework and Implementation Guidelines for Planners and Managers,* PRETORIA: Water Research Commission (WRC).

Lin, H. & Thornton, J. A., 2014. Integrated Payments for Ecosystem Services: A Governance Path from Lakes and Rivers to Coastal Areas in China. In: E. Y. Mohammed, ed. *Economic Incentives for Marine and Coastal Conservation: Prospects, and Policy Implications.* New York: Routledge, pp. 69-92.

Louw, T., 2022. *Lab analysis for phosphorus and nitrogen* [Interview] [18 10 2022].

Maavara, T. et al., 2015. Global phosphorus retention by river damming. *Proceedings of the National Academy of Science of the United States of America,* 112[51], p. 15603–15608.

Macfarlane, D. M. et al., 2009. *Development of a methodology to determine the appropriate buffer zone width and type for developments associated with wetlands, rivers and estuaries. Deliverable 4: Revised conceptual framework for buffer determination. Report submitted to the WRC and DWA,* PRETORIA: Institute of Natural Resources (INR Report No. 414/09).

Matachi, A., 2006. *Capacity Building Framework,* ADDIS ABABA: United Nations Economic Commission for Africa.

Matthews, M. & Kravitz, J., 2022. *EONEMP II Draft Final Report, Project No. C2019 2020-00198,* PRETORIA: Water Research Commission (WRC).

Matthews, M. W., 2014. Eutrophication and cyanobacterial blooms in South African inland waters: 10 years of MERIS observations. *Remote Sensing of Environment, 155, 161–177.,* Volume 155, pp. 161 - 177.

Matthews, M. W. & Bernard, S., 2015. Eutrophication and cyanobacteria in South Africa's standing water bodies: A view from space. *South African Journal of Science,* 111[5], p. 8.

Miller, T. G., 1998. *Living in the Environment - Principles, Connections and Solutions.* 10 ed. BELMONT, CA: Wadsworth Publishing Company, An International Thompson Publishing Company.

Mitchell, S. A. et al., 2016. *Review of the Hartbeespoort Dam Integrated Biological Remediation Programme - Harties Metsi a Me (WRC Project No K8/1083),* PRETORIA: Water Research Commission (WRC).

Moen, R. & Norman, C., 2009. *Evolution of the PDCA Cycle.* TOKYO, Proceedings of the 7th American Notes and Queries (ANQ) Congress.

Mooij, W. M., Janse, J. H. & De Senerpont Domis, L. N., 2007. Predicting the effect of climate change on temperate shallow lakes with the ecosystem model PCLake. *Hydrobiologia,* Volume 584[A], pp. 443-454.

Morgan, P., 1998. *Capacity and Capacity Development - Some Strategies. Note prepared for the Political and Social Policies Division Policy branch, CIDA,* s.l.: s.n.

Moss, B., 1999. *Eutrophicalion and eutrophication research in South Africa - An independent view (Report to Lever Pond's),* DURBAN: Lever Pond's.

Mudaly, L. & van der Laan, M., 2020. Interactions between Irrigated Agriculture and Surface Water Quality with a Focus on Phosphate and Nitrate in the Middle Olifants Catchment, South Africa. *Sustainability,* 12[4370], pp. 1-25.

Muller, M. & Erasmus, J., 2020. *Corruption in South Africa's Water Sector,* JOHANNESBURG: Water Integrity Network and Corruption Watch.

Nathan, J. D., 2018. Is the Natural Step’s theory about Sustainability still Sustainable? A theoretical review and critique. *Journal of Sustainable Development,* 11[1], pp. 125-139.

Naumann, E., 1929. The scope and chief problems of regional limnology. *Int Revue Ges Hydrobiol,* p. 21: 423.

Nazari-Sharabian, M., Ahmad, S. & Karakouzian, M., 2018. Climate change and eutrophication: A short review. *Engineering, Technology & Applied Science Research,* Volume 8[6], pp. 3668-3672.

Nel, J. et al., 2013. *Defining South Africa’s Water Source Areas,* CAPE TOWN: World Wildlife Fund (WWF) - South Africa.

Nepfumbada, M. P. & Seetal, A., 2020. *National Water Security Framework for South Africa: Summary, Principles and Recommendations from the 1st Edition,* PRETORIA: Produced for the National Planning Commission.

Nicholls, H. A., Osborn, D. W. & Pitman, A. R., 1986. Biological phosphorus removal at the Johannesburg Northern and Goudkoppies wastewater purification plants. *Water SA,* 12[1], pp. 13-18.

NPC, 2012. *National Development Plan 2030 - Our future, make it work,* PRETORIA: National Planning Commission (NPC), Republic of South Africa (RSA).

Oberholster, P. J., Dabrowski, J. & Botha, A.-M., 2013. Using modified multiple phosphorus Sensitivity Indices for mitigation and management of phosphorus loads on a catchment level. *Fundamental and Applied Limnology ,* 182[1], pp. 1-16.

OECD, 1982. *Eutrophication of waters: Monitoring, Assessment and Control,* PARIS: Organisation for Economic Cooperation and Development (OECD).

OECD, 1991. *Environmental Labelling in OECD Countries,* PARIS: Organization for Economic Cooperation and Development (OECD).

OECD, 2009. *Determination and Application of Administrative Fines for Environmental Offences: Guidance for Environmental Enforcement Authorities in EECCA Countries,* PARIS: Organisation for Economic Co-operation and Development (OECD).

OECD, 2017. *Diffuse pollution - Degraded waters: Emerging policy solutions (Policy highlights),* PARIS: Organisation for Economic Co-operation and Development (OECD).

Oelofse, S. H., Viljoen, P., Taljaard, S. & Botes, W. A., 2004. Discharge of water containing waste emanating from land to the marine environment: A water quality management perspective. *Water SA,* 30[5], pp. 56-60.

Officer, C. B. & Ryther, J. H., 1980. The possible importance of silicon in marine eutrophication. *Marine Ecology Progress Series,* Volume 3, pp. 83-91.

Osborn, D. W., 1988. Sewage purification in South Arica - Past and present. *Water SA,* 14[3], pp. 139-151.

Padedda, B. M. et al., 2017. Consequences of eutrophication in the management of water resources in Mediterranean reservoirs: A case study of Lake Cedrino (Sardinia, Italy). *Global Ecology and Conservation,* Volume 12, pp. 21-35.

Pillay, M. & Buckley, C. A., 2001. *Detergent Phosphorus in South Africa: Impact on Eutrophication with Specific Reference to the Mgeni Catchment - WRC Report No: 465/1/01,* PRETORIA: Water Research Commission (WRC).

Post, W. M. et al., 1990. The global carbon cycle. *American Scientist,* Volume 78, pp. 310-326.

Presidency, T., 2020. *National Policy Development Framework,* CAPE TOWN: The Presidency: Republic of South Africa.

Pretorius, W. A., 1983. Should the phosphate concentration in sewage effluents be restricted?. *IMIESA,* Volume 8, pp. 23-29.

Quayle, L. M. et al., 2010. *Investigation of the positive and negative consequences associated with the introduction of zero-phosphate detergents into South Africa (Report TT 446/10),* PRETORIA: Water Research Commission (WRC).

Rast, W., Holland, M. & Ryding, S.-O., 1989. *Eutrophication Management Framework for the Policy-Maker.* Man and Biosphere (MAB) Digest #1 ed. Austin, TX: United Nations Educational, Scientific and Cultural Organization (UNESCO), United Nations (UN).

Rast, W. & Thornton, J. A., 1996. Trends in eutrophication research and control. *Hydrological Processes,* Volume 10[February], pp. 295-313.

Reese, M., 2020. A look at acid rain and the farm phosphorus conundrum with water quality. *Ohio State University (College of Food, Agriculture and Environmental Science) Country Journal.*

Richardson, P. & Van Helten, J.-J., 1984. The Development of the South African Gold-Mining Industry: 1995-1918. *The Economic History Review,* 37[3], pp. 319-340.

Riddell, E., 2021. *Eutrophication* [Interview] [22 July 2021].

Robarts, R. D. & Zohary, T., 1984. Mycrocystis aeruginosa and underwater light attenuation in a hypertrophic lake (Hartbeespoort Dam, South Africa). *Journal of Ecology,* 72[3], pp. 1001-1017.

Robarts, R. D. & Zohary, T., 1992. The influence of temperature and light on the upper limit of Microcystis aeruginosa production in a hypertrophic reservoir. *Journal of Plankton Research,* 14[2], pp. 235-247.

Robèrt, K.-H., 2008. In: *The Natural Step Story: Seeding a Quiet Revolution.* s.l.:New Society Publishers, p. 288.

Rogers, P. J., 2000. Causal models in program theory evaluation. *New directions for evaluation,* Volume 87, pp. 47-55.

Rooney, J. J. & Van den Heuvel, L. N., 2004. Root Cause Analysis for Beginners. *Quality Basics,* pp. 45-53.

Roos, J. C., 2009. *Vaal River - Eutrophication Status,* PRETORIA: Unpublished report.

Ross-Gillespie, V. et al., 2015. *ORASECOM Joint Basin Survey 2: Aquatic Ecosystem Health and Water Quality Monitoring,* PRETORIA: Orange Senqu River Commission (ORASECOM).

Rossouw, J. N. & Forster, L., 2008. *Business Support for Water Quality Planning Systems: Guide to the Visual Assessment of Eutrophication Problems,* PRETORIA: Departartment of Water Affairs and Forestry (DWAF).

Roux , D. J. et al., 1999. Integrating Stressor and Response Monitoring into a Resource-Based Water Quality Assessment Framework. *Env. Management,* 23[1], pp. 15-30.

SA Commission of Enquiry into Water Matters, 1970. *Report of the South African (SA) Commission of Enquiry into Water Matters,* s.l.: s.n.

SADC, 2000. *Revised Protocol on Shared Watercourses in the Southern African Development Community (SADC),* PRETORIA: Southern African Development Community (SADC).

SANBI, 2014. *A Framework for Investing in Ecological Infrastructure in South Africa,* Pretoria: South African National Biodiversity Institute (SANBI).

Sanitation, D. o. W. a., 2017. *Water Quality Managment Policies and Strategies for South Africa,* Pretoria: s.n.

Savitri, J. & Gail, K., 2016. Adaptive capacity for eutrophication governance of the Laurentian Great Lakes. *Electronic Green Journal,* 1[39].

Scherman, P., 2008. *Methods for determining the water quality component of the Ecological,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

Schmutz, S. & Sendzimir, J., 2018. *Riverine ecosystem management - Science for governing towards a sustained future.* CHAM: Springer.

Schreiner, B. & Hassan, R., 2011. *Transforming Water Management in South Africa: Designing and Implementing a New Policy Framework.* DORDRECHT: Springer Science + Business Media.

Shigley, J., 2017. *Historical Reading List: The Diamond Fields of South Africa: Part 1 (1868-1893).* s.l.:s.n.

Silberbauer, M. J., 2022. *Eutrophication* [Interview] [01 08 2022].

Smeets, E. & Weterings, R., 1999. *Environmental indicators: Typology and overview, Technical report No. 25,* COPENHAGEN: European Environment Agency.

Society, N. A. L. M., 2001. *Managing Lakes and Reservoirs,* MADISON, WI: North American Lake Management Society and the Terrene Institute in cooperation with the US EPA.

Stats SA, 2003. *Statistics South Africa: Census 2001 (Report no. 03-02-03, 2001),* PRETORIA: Statistics South Africa.

Stats SA, 2007. *Community Survey 2007 (Statistical Release P0301),* PRETORIA: Statistics South Africa.

Stats SA, 2016. *Community Survey 2016 (Statistical Release P0301),* PRETORIA: Statistics South Africa.

Stein, R., 2002. *Water Law in a Democratic SA: A country case study examining the introduction of a Public Rights System. Notes for a panel presentation, Summer Conference (June 11-14): Allocating and Managing water for a Sustainable Future: Lessons from around the world.* s.l., Natural Resources Law Center, University of Colorado School of Law.

Stewart, K. M. & Rohlich, G. A., 1967. *Eutrophication - A review (publication no.34),* SACRAMENTO: California Water Quality Control Board.

Stockner, J. G., Rydin, E. & Hyenstrand, P., 2000. Cultural Oligotrophication: Causes and Consequences for Fisheries Resources. *Fisheries Habitat - Perspective,* 25[5], pp. 7-14.

Taylor, R., Best, H. J. & Wiechers, H. N. S., 1984. *The effluent phosphate standard in perspective: Part 1: Impact, control and management of eutrophication,* PRETORIA: IMIESA.

Thompson, H., 2016. *Water Law - A practical approach to Resource Management & the provision of Services.* 1 ed. CAPE TOWN: Juta.

Thornton, J., 2021. *Eutrophication* [Interview] [21 July 2021].

Thornton, J. A. et al., 2013. Eutrophication as a 'wicked' problem. *Lakes and Reservoirs: Research and Management,* Volume 18, pp. 298-316.

Toerien, D. F., 1984. *Personal Communication,* PRETORIA: National Institute for Water Research (NIWR), Council for Scientific and Industrial Research (CSIR).

Toerien, D. F., Hyman, K. L. & Bruwer, M. J., 1975. A preliminary Trophic Status Classification of some South African Impoundments. *Water SA,* 1[1], pp. 15-23.

UN, 2015a. *The Millennium Development Goals Report,* NEW YORK: United Nations (UN).

UN, 2015b. *Transforming our World: The 2030 Agenda for Sustainable Development,* NEW YORK: United Nations (UN).

UNCED, 1992. *Agenda 21, Rio Declaration on Environment and Development, and Forest Principles,* NEW YORK: United Nations Conference on Environment and Development (UNCED), United Nations (UN).

UNEP, 2016. *A Snapshot of the World's Water Quality: Towards a global assessment,* NAIROBI, Kenya: United Nations Environment Programme (UNEP).

US EPA, 2006. *Life Cycle Assessment: Principles and Practice. 2006. pp. 3–9.,* Cincinnati, Ohio: United States (US) Environmental Protection Agency (EPA).

Uys, M., 2008. *Water Law of South Africa 1912 to 1998. WRC Report No. KV 203/08,* PRETORIA: Water Research Commission (WRC).

Van Baalen, M., Schutte, C. & Von Leipzig, K., 2015. Capacity self-assessment as a catalyst for improved municipal service delivery. *Journal of the South African Institution of Civil Engineering (SAICE),* 57[1], pp. 2-15.

Van Ginkel, C. E., 2011. Eutrophication: Present reality and future challenges for South Africa. *Water SA,* 37[5], pp. 693-701.

Van Ginkel, C. E., 2022. *Eutrophication* [Interview] [19 07 2022].

Van Ginkel, C. E. et al., 2000a. *Assessment of the Trophic Status Project,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

Van Ginkel, C. E., Silberbauer, M. J. & Vermaak, E., 2000b. The seasonal and spatial distribution of cyanobacteria in South African surface waters. *Proceedings of the International Society of Limnology, 1922-2010,* Volume 27[2], pp. 871 - 878.

Van Niekerk, A., 2000. *Technological perspectives on the new South African effluent (waste) standards.* SUN CITY, Paper presented at Water Institute of Southern Africa (WISA) 2000 Biennial Conference (28 May to 1 June), p. 12.

Van Niekerk, H., 2004. *UNEP Global Environmental Monitoring System/ Water Programme: South African Monitoring Programme Design,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

Van Wyk, J. J. et al., 2020. *Methodology Report: SDG Target 6.3 - Water quality and wastewater, Edition 1 (Version 11),* PRETORIA: Department of Water and Sanitation (DWS).

Van Wyk, J. J., Moodley, P. & Viljoen, P., 2003. *Towards Balancing Water Resources Protection with Water Resource Use and Development: Integrated Water Quality Management in South Africa.* STELLENBOSCH, Second International Symposium on Integrated Water Resource Management (IWRM).

Venter, F. A., 1971. *Water.* JOHANNESBURG: Afrikaanse Pers-Boekhandel vir die Ministerie van Waterwese.

Vienings, A. et al., 2015. *Integrated Water Sector Skills Intervention Map based on a Sector Skills Gap Analysis,* PRETORIA: Water Research Commission (WRC).

Vogel, R. M., Wilson, I. & Daly, C., 1999. Regional regression models of annual streamflow for the United States. *Journal of Irrigation and Drainage Engineering,* Volume 125[3], pp. 148-157.

Vollenweider, R. A., 1968. *Scientific fundamentals of the eutrophication of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in eutrophication,* PARIS: Organisation for Economic Cooperation and Development (OECD).

Vollenweider, R. A. & Kerekes, J. J., 1980. Background and summary results of the OECD cooperative program on eutrophication. *Proceedings of an International Symposium on Inland Waters and Lake Restoration,* Volume U.S. Environmental Protection Agency, EPA-822-B00-001, pp. 26-36.

Wall, K., 2018. The evolution of South African wastewater effluent parameters and their regulation: A brief history of the drivers, institutions, needs and challenges. *The Journal for Transdisciplinary Research in Southern Africa,* 14[1], pp. 1-11.

Walmsley, R. D., 2000. *Perspectives on Eutrophication of Surface Waters: Policy/ Research needs in South Africa. WRC Report No. KV129/00,* PRETORIA: Water Research Commission (WRC).

Walmsley, R. D., 2003. *A Review and Discussion Document: Development of a Strategy to Control Eutrophication in South Africa,* PRETORIA: Department of Water Affairs and Forestry (DWAF).

Walmsley, R. D. & Butty, M., 1980. *Limnology of some selected South African impoundments.,* PRETORIA: Water Research Commission (WRC).

Wetzel, R. D., 2001. *Limnology: Lake and River Ecosystems,* San Diego: Academic Press.

Whitehead, P. G., Wilby, R. L. & Battarbee, R. W., 2009. A review of the potential impacts of climate change on surface water quality. *Hydrological Sciences Journal,* Volume 54[1], pp. 101-123.

Win-SA, 2015. *Lesson Series: Water Sector Skills Gap Analysis - A Skills Intervention Map for South Africa,* PRETORIA: Water Research Commission (WRC).

Withers, P. J., Neal, C., Jarvie, H. P. & Doody, D. G., 2014. Agriculture and Eutrophication: Where do we go from here?. *Sustainability,* Volume 6, pp. 5853-5875.

WRC, 2011. *Technical Brief: Water Research Commission supported eutrophication research and its impacts,* PRETORIA: Water Reserach Commission (WRC).

WRC, 2014. *Ecological Infrastructure for Water Security.,* PRETORIA: Minister's approved draft for submission to the Presidential Infrastructure Coordinating Commission (PICC).

WSSD, 2002. *Johannesburg Declaration on Sustainable Development and Plan of Implementation of the World Summit on Sustainable Development: the final text of agreements negotiated by governments at the World Summit on Sustainable Development,* NEW YORK: World Summit on Sustainable Development (WSSD), United Nations Department of Public Information.

Zhang, Y. et al., 2020. Control and remediation methods for eutrophic lakes in the past 30 years. *International Water Association (IWA) Publishing - Water Science,* 81[6], pp. 1099 - 1113.

Zohary, T. et al., 1988. *The Hartbeespoort Dam Ecosystem Programme,* PRETORIA: Council for Scientific and Industrial Research (CSIR) & Water Research Commission (WRC).

URL INTERNET REFERENCES

DWS, 2021. *Department of Water and Sanitation (DWS): 2020 Vision for Water and Sanitation Education Programme (2020 VfWSEP).* [Online]
Available at: https://www.dws.gov.za/2020Vision/default.aspx
[Accessed 20 July 2021].

Ecolabel Index, 2021. *Ecolabel Index is the largest global directory of ecolabels, currently tracking 456 ecolabels in 199 countries and 25 industry sectors.* [Online]
Available at: https://www.ecolabelindex.com/
[Accessed 15 September 2021].

Ramsar, 2021. *Ramsar Convention of Wetlands/ South Africa.* [Online]
Available at: https://www.ramsar.org/wetland/south-africa
[Accessed 05 June 2021].

UNESCO, I. H. P., 2021. *FETWATER Framework Programme for Research, Education and Training in the Water Sector.* [Online]
Available at: http://fetwater.co.za/
[Accessed 17 July 2021].

UN Water, 2013. *United Nations: UN Water: What is Water Security? Infographic.* [Online]
Available at: https://www.unwater.org/publications/water-security-infographic/
[Accessed 8 February 2021].

ANNEXURE A

Human health and other effects of water resources that are unfit-for-use, with respect to some eutrophication-related water quality indicators (parameters).

ANNEXURE A

Human health and other effects of water resources that are unfit-for-use, with respect to some eutrophication-related water quality indicators (parameters).
[Scherman, 2008; DWAF, 1996]

ALPHABETICALLY ARRANGED PARAMETERS	APPLICABLE CONCENTRATION RANGES	EXPECTED EFFECT CAUSED BY WATER RESOURCES WITH WATER QUALITY IN THE UNACCEPTABLE CONCENTRATION RANGE	RECEIVING WATER USER
Algae *[free floating green algae/ phytoplankton]*	***Aesthetics:*** I: <=15 µg Chl-α/ℓ A: >15 to <=22.5 µg Chl-α/ℓ T: >22.5 to <=30 µg Chl-α/ℓ U: >30 µg Chl-α/ℓ	Severe nuisance conditions may be encountered. Aesthetically unacceptable surface algal scums evident for much of the time. The composition and health of the fish population may be affected, depending on species. Rotting algae may cause severe odour problems. No health effects expected.	**Recreation: Full-contact**
	Aesthetics: I: <=20 µg Chl-α/ℓ A: >20 to <=25 µg Chl-α/ℓ T: >25 to <=30 µg Chl-α/ℓ U: >30 µg Chl-α/ℓ	Severe nuisance algal blooms (scums) as well as other symptoms of eutrophication. Rotting algae may cause severe odour problems. No health effects expected.	**Recreation: Non-contact**
Algae *[blue-green algae/ cyanobacteria]*	***Human health:*** I: <=50 colonies/mℓ A: >50 to <=14 000 colonies/mℓ T: >14 000 to <=42 000 colonies/mℓ U: >42 000 colonies/mℓ	Significant risk of acute and chronic effects associated with the ingestion of the algae.	**Domestic**
	Human health: I: <=6 blue-green algae units* A: - T: - U: >6 blue-green algae units	Blue-green algae present in significant numbers and scum formation likely. Recreational users should increase their vigilance for algal scums and avoid all contact with scums. Notices warning users to avoid algal scums should be posted. Health effects likely with accidental ingestion of the scums and skin irritations likely with contact with the scums.	**Recreation: Full-contact**

ALPHABETICALLY ARRANGED PARAMETERS	APPLICABLE CONCENTRATION RANGES	EXPECTED EFFECT CAUSED BY WATER RESOURCES WITH WATER QUALITY IN THE UNACCEPTABLE CONCENTRATION RANGE	RECEIVING WATER USER
	Health of livestock: I: <=12 colonies/mℓ; and <=2 000 Microcystis colonies/ mℓ A: - T: >12 colonies/mℓ; and <=2 000 Microcystis colonies/ mℓ U: >12 colonies /mℓ; and >2 000 Microcystis colonies/ mℓ	High risk of acute toxic effects. Do not allow livestock to drink from or have contact with the scum.	**Agriculture: Livestock watering**
Algae *[chlorophyll-α]*	***Aesthetics:*** I: <=1 µg Chl-α/ℓ A: >1 to <=15 µg Chl-α/ℓ T: >15 to <=100 µg Chl-α/ℓ U: >100 µg Chl-α/ℓ	Water has a distinct murky appearance, becoming increasingly green in colour. Significant taste and odour problems. Secondary growth of bacteria in the distribution system.	**Domestic**
Algae *[microcystins (hepatotoxins produced by algae)]*	***Human health:*** I: <=0.8 µg/ℓ A: >0.8 to <=0.9 µg/ℓ T: >0.9 to <=1 µg/ℓ U: >1 µg/ℓ	Possible acute hepatotoxic effects.	**Domestic**
Free ammonia *[NH_3]*	***Human health and Aesthetics:*** I: <=1.0 mg N/ℓ (pH>8) A: >1.0 to <=2.0 mg N/ℓ (pH>8) T: >2.0 to <=10.0 mg N/ℓ (pH>8) U: >10.0 mg N/ℓ (pH>8)	Unacceptable in domestic water. Danger of formation of nitrite. Likelihood of fish deaths in aquaria. Chlorination is severely compromised.	**Domestic**

ALPHABETICALLY ARRANGED PARAMETERS	APPLICABLE CONCENTRATION RANGES	EXPECTED EFFECT CAUSED BY WATER RESOURCES WITH WATER QUALITY IN THE UNACCEPTABLE CONCENTRATION RANGE	RECEIVING WATER USER
	Aquatic ecosystem health: I: <=15.0 µg N/ℓ (pH>8) A: >15.0 to <=72.5 µg N /ℓ (pH>8) T: >72.5 to <=100 µg N /ℓ (pH>8) U: >100 µg N /ℓ (pH>8)	The toxicity of ammonia and ammonium salts to aquatic organisms is directly related to the amount of free ammonia in solution. At low to medium pH values, the ammonium ion dominates, but as pH increases free ammonia is formed, the latter being considerably more toxic to aquatic organisms. Free un-ionized ammonia affects the respiratory systems of many animals, either by inhibiting cellular metabolism or by decreasing oxygen permeability of cell membranes. Acute toxicity to fish may cause a loss of equilibrium, hyper-excitability, an increased breathing rate, an increased cardiac output and oxygen intake, and in extreme cases convulsions, coma and death. Chronic effects include a reduction in hatching success, reduction in growth rate and morphological development, and pathological changes in tissue of gills, liver and kidneys.	**Aquatic ecosystem**
Clarity	***Human health & Aesthetics:*** I: >=3.0 m (Secchi depth) A: <3.0 to >=1.5 m (Secchi depth) T: <1.5 to >=1.0 m (Secchi depth) U: <1.0 m (Secchi depth)	Unsuitable for swimming. However, if lack of clarity (or turbidity) is the only consideration preventing the use of a waterbody for swimming, then it may be allowed, provided all subsurface, potential hazards are removed and signs indicating water depth are clearly posted. Risk of disease transmission by organisms associated with particulate matter increases, but this cannot solely be determined based on clarity measurements. There may be some depreciation in aesthetic quality and enjoyment of the waterbody.	**Recreation: Full-contact**
Dissolved Oxygen *[DO]*	***Aquatic ecosystem health:*** I: >=80% A: <80% to 70% T: <70% to 60% U: <60% *(7 day mean)*;and <40% *(1 day minimum)*	The 7-day mean minimum and the 1-day minimum should apply together. Violation of these minimum values is likely to cause acute toxic effects on aquatic biota.	**Aquatic ecosystem**
Dissolved Organic Carbon *[DOC]*	***Human health:*** I: <=5 mg C/ℓ A: >5 to <=10 mg C/ℓ T: >10 to <=20 mg C/ℓ U: >20 mg C/ℓ	Aesthetic effects (taste, odour, colour) and formation of trihalomethanes (THMs) during chlorination. Marked health effects, depending on the composition of the DOC.	**Domestic**
Nitrate/Nitrite *[NO_2^-/NO_3^-]*	***Human health:*** I: <=6 mg N/ℓ A: >6 to <=10 mg N/ℓ T: >10 to <=20 mg N/ℓ U: >20 mg N/ℓ	Upon absorption, nitrite combines with the oxygen-carrying red blood pigment, haemoglobin, to form methaemoglobin, which is incapable of carrying oxygen. This condition is termed methaemoglobinaemia. The reaction of nitrite with haemoglobin can be particularly hazardous in infants under three months of age and is compounded when the intake of Vitamin C is inadequate. Occurrence of mucous membrane irritation in adults.	**Domestic**

ALPHABETICALLY ARRANGED PARAMETERS	APPLICABLE CONCENTRATION RANGES	EXPECTED EFFECT CAUSED BY WATER RESOURCES WITH WATER QUALITY IN THE UNACCEPTABLE CONCENTRATION RANGE	RECEIVING WATER USER
	Health of livestock: I: <=100 mg N/ℓ A: >100 to <=200 mg N/ℓ T: >200 to <=400 mg N/ℓ U: >400 mg N/ℓ	Adverse chronic effects, such as restlessness, frequent urination, dyspnoea, cyanosis associated with methaemoglobinemia and decreased feed and water intake associated with adverse palatability effects may occur, but can be tolerated if- ▶ feed concentration is normal; ▶ there is adequate carbohydrate intake; and ▶ exposure is short term. Acute effects such, as severe gastroenteritis in non-ruminants and acute methaemoglobinemia in ruminants (severe dyspnoea and cyanosis) may occur. May be tolerated under certain conditions, depending on site-specific factors such as nutritional carbohydrate levels, TDS and sulphate concentrations in the water, and the type of micro-organisms present in the rumen.	**Agriculture: Livestock watering**
Nitrogen (inorganic) *[TIN]*	***Crop yield and Groundwater:*** I: <=0.5 mg total N/ℓ A: >0.5 to <=5 mg total N/ℓ T: >5 to <=30 mg total N/ℓ U: >30 mg total N/ℓ	Most crops are affected. A limited range of crops can utilise the nitrogen applied. Severe restrictions are placed on the utilisation of these waters. Increasingly serious likelihood of ground water contamination.	**Agriculture: Irrigation**
	Irrigation equipment: I: <=0.5 mg total N/ℓ A: >0.5 to <=2.5 mg total N/ℓ T: >2.5 to <=10 mg total N/ℓ U: >10 mg total N/ℓ	Hypertrophic conditions. Almost continuous growth of nuisance plants and blue-green algal blooms in irrigation structures in the absence of other growth-limiting factors.	**Agriculture: Irrigation**

ALPHABETICALLY ARRANGED PARAMETERS	APPLICABLE CONCENTRATION RANGES	EXPECTED EFFECT CAUSED BY WATER RESOURCES WITH WATER QUALITY IN THE <u>UNACCEPTABLE</u> CONCENTRATION RANGE	RECEIVING WATER USER
	<u>Aquatic ecosystem health</u>: I: <=0.25 mg total N/ℓ A: >0.25 to <=1.00 mg total N/ℓ T: >1.00 to <=4 mg total N/ℓ U: >4 mg total N/ℓ ▶ *Inorganic nitrogen concentrations should not be changed by more than 15 % from that of the waterbody under local unimpacted conditions at any time of the year; and* ▶ *The trophic status of the waterbody should not increase above its present level, though a decrease in trophic status is permissible; and* ▶ *The amplitude and frequency of natural cycles in inorganic nitrogen concentrations should not be changed.*	Hypertrophic conditions; usually very low levels of species diversity; usually very highly productive systems; nuisance growth of aquatic plants and blooms of blue-green algae, often including species which are toxic to man, livestock and wildlife.	**Aquatic ecosystem**
Odour	***<u>Aesthetics</u>:*** I: <=1 TON A: >1 to <=5 TON T: >5 to <=10 TON U: >10 TON	The odour of water becomes stronger and increasingly objectionable	**Domestic**
Orthophosphate (soluble) *[PO_4]*	***<u>Aquatic ecosystem health</u>:*** I: <=0.01 mg P/ℓ A: >0.01 to <=0.03 mg P/ℓ T: >0.03 to <=0.13 mg P/ℓ U: >0.13 mg P/ℓ	Hypertrophic conditions; usually very low levels of species diversity; usually very highly productive systems; nuisance growth of aquatic plants and blooms of blue-green algae, often including species which are toxic to man, livestock and wildlife.	**Aquatic ecosystem**

ALPHABETICALLY ARRANGED PARAMETERS	APPLICABLE CONCENTRATION RANGES	EXPECTED EFFECT CAUSED BY WATER RESOURCES WITH WATER QUALITY IN THE UNACCEPTABLE CONCENTRATION RANGE	RECEIVING WATER USER
Phosphorus (inorganic) *[TP]*	***Aquatic ecosystems:*** I: <=5 µg total P/ℓ A: >5 to <=25 µg total P/ℓ T: >25 to <=250 µg total P/ℓ U: >250 µg total P/ℓ ▶ *Inorganic phosphorus concentrations should not be changed by >15 % from that of the waterbody under local, unimpacted conditions at any time of the year; and* ▶ *The trophic status of the waterbody should not increase above its present level, though a decrease in trophic status is permissible; and* ▶ *The amplitude and frequency of natural cycles in inorganic phosphorus concentrations should not be changed.*	Hypertrophic conditions; usually very low levels of species diversity; usually very highly productive systems; nuisance growth of aquatic plants and blooms of blue-green algae, often including species which are toxic to man, livestock and wildlife.	**Aquatic ecosystem**
Turbidity	***Human health and Aesthetics:*** I: <=1 NTU A: >1 to <=5 NTU T: >5 to <=10 NTU U: >10 NTU	Severe aesthetic effects (appearance, taste and odour). Water carries an associated risk of disease due to infectious disease agents and chemicals adsorbed onto particulate matter. A chance of disease transmission at epidemic level exists at high turbidity.	**Domestic**
Nuisance water plants	***Swimming:***	The growth of aquatic vascular plants in waterbodies used for full-contact recreation should be limited to ensure that entanglement of swimmers does not occur and that plants do not obscure visibility. Excessive plant growth should not occur in full-contact recreational areas. The presence of floating masses of detached plants which may obstruct water users are aesthetically objectionable and provide a habitat for the growth of nuisance and vector organisms (for example insects, fungi and bacteria) and should be limited as far as possible.	**Recreation: Full-contact**

ALPHABETICALLY ARRANGED PARAMETERS	APPLICABLE CONCENTRATION RANGES	EXPECTED EFFECT CAUSED BY WATER RESOURCES WITH WATER QUALITY IN THE UNACCEPTABLE CONCENTRATION RANGE	RECEIVING WATER USER
	Intermediate contact recreation:	Since activities involving intermediate-contact recreation may include occasional full-body immersion, the criteria given above should be used and the extent of contact should be taken into account. Where water contact is slight or infrequent, the criteria may be applied less stringently. Plant growth should also be limited to prevent possible entanglement of boats, water skiers and boardsailors.	**Recreation: Intermediate-contact**
	No contact recreation:	Aquatic plant growth should not detract from the aesthetic aspects of waterbodies used for non-contact recreation. Hence, water should not be completely covered, plant growth should not be unsightly or cause unpleasant odours, and there should be no adverse effects on other aquatic organisms.	**Recreation: Non-contact**

*** Key:**

- **I**=Ideal; **A**=Acceptable; **T**=Tolerable; and **U**=Unacceptable; and
- *"Blue-green algae units"* refers to the number of blue-green units (colonies and filaments) counted in a two-minute scan of 0.5 mℓ of water at x200 magnification.

ANNEXURE B

The nature of *"wicked problems"*.

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The nature of *"wicked problems"*.

The characteristics of a *"wicked problem"*, according to Thornton (2013), are:

1. There is no single answer applicable to resolving a wicked problem;
2. There is no end point in implementing a solution to a wicked problem;
3. There are no true–false answers to resolving a wicked problem;
4. There is no complete *ante facto* understanding of the outcomes associated with interventions intended to resolve a wicked problem;
5. Every solution applied to a wicked problem is unique and has a unique outcome;
6. There is no fixed number of approaches that will resolve a wicked problem;
7. Every wicked problem is unique;
8. Every wicked problem is a symptom of another problem;
9. The application of one intervention to resolve a specific wicked problem may have a different outcome when applied to a similar problem in a different location; and
10. *"The planner has no right to be wrong"*.

ANNEXURE C

Supporting National Environmental Management Principles.

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Supporting National Environmental Management Principles.

NEMA (107:1998) sets out the following national environmental management principles, which also have relevance to eutrophication management:

- **Environmental management must be integrated**, acknowledging that all elements of the environment are linked and interrelated, and it must take into account the effects of decisions on all aspects of the environment and all people in the environment by pursuing the selection of the **best practicable environmental option**;
- **Environmental justice must be pursued** so that adverse environmental impacts shall not be distributed in such a manner as to unfairly discriminate against any person, particularly vulnerable and disadvantaged persons;
- **Equitable access to environmental resources**, benefits and services to meet basic human needs and ensure human well-being must be pursued and special measures may be taken to ensure access thereto by categories of persons disadvantaged by unfair discrimination;
- Responsibility for the environmental health and safety consequences of a policy, programme, project, product, process, service or activity **exists throughout its life cycle**;
- The **participation of all interested and affected parties** in environmental governance must be promoted, and all people must have the opportunity to develop the understanding, skills and capacity necessary for achieving equitable and effective participation, and participation by vulnerable and disadvantaged persons must be ensured;
- Decisions must take into account the interests, needs and values of all interested and affected parties, and this includes **recognizing all forms of knowledge**, including specialist, traditional and common knowledge;
- Community wellbeing and empowerment must be promoted through **environmental education, the raising of environmental awareness**, the sharing of knowledge and experience and other appropriate means;
- The **social, economic and environmental impacts** of activities, including disadvantages and benefits, must be considered, assessed and evaluated and decisions must be appropriate in the light of such consideration and assessment;
- The **right of workers to refuse work that is harmful** to human health or the environment and to be informed of dangers must be respected and protected;
- Decisions must be taken in an **open and transparent** manner, and access to information must be provided in accordance with the law;
- There must be **intergovernmental co-ordination and harmonisation** of policies, legislation and actions relating to the environment;
- Actual or potential **conflicts of interest between organs of state** should be resolved through conflict resolution procedures;
- **Global and international responsibilities** relating to the environment must be given effect, in the national interest;
- The environment is held in **public trust** for the people. The beneficial use of environmental resources must serve the public interest and the environment must be protected as the people's common heritage;
- The **costs to remedy pollution**, environmental degradation and consequent adverse health effects, and to prevent, control or minimise further pollution, environmental damage or adverse health effects, must be paid for by those responsible for harming the environment;

- The **vital role of women and youth** in environmental management and development must be recognised and their full participation therein must be promoted; and
- **Sensitive, vulnerable, highly dynamic or stressed ecosystems**, such as coastal shores, estuaries, wetlands and similar systems require specific attention in management and planning procedures, especially where they are subject to significant human resource usage and development pressure.

ANNEXURE D

The 28 Fundamental Principles and Objectives for a New Water Law in South Africa (1996), from a eutrophication management perspective.

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The 28 Fundamental Principles and Objectives for a New Water Law in South Africa (1996), from a eutrophication management perspective.

Water law in South Africa is based on 28 fundamental principles and objectives, as approved by Cabinet in November, 1996 [Stein, 2002]. Eutrophication management policy and strategy, broadly, should conform to these fundamental principles and objectives, especially the 13 principles and objectives that are of foremost relevance to eutrophication management, as summarised below:

LIST OF 13 PRINCIPLES AND OBJECTIVES MOST RELEVANT TO EUTROPHICATION MANAGEMENT:
The water cycle
Principle 5: In a relatively arid country such as South Africa, it is necessary to recognise the **unity of the water cycle** and the interdependence of its elements, where evaporation, clouds and rainfall are linked to groundwater, rivers, lakes, wetlands and the sea, and where the **basic hydrological unit is the catchment**.
Water resource management priorities
Principle 7: **The objective of managing the quantity, quality and reliability** of the Nation's water resources is to achieve optimum, long term, environmentally sustainable social and economic benefit for society from their use.
Principle 9: The quantity, quality and reliability of water required to maintain the **ecological functions on which humans depend** shall be reserved so that the human use of water does not individually or cumulatively compromise the long-term sustainability of aquatic and associated ecosystems.
Principle 13: As custodian of the Nation's water resources, the National Government shall ensure that the development, apportionment, management and use of those resources is carried out using the criteria of **public interest, sustainability, equity and efficiency** of use in a manner which reflects its public trust obligations and the value of water to society, while ensuring that basic domestic needs, the requirements of the environment and **international obligations** are met.
Principle 14: Water resources shall be developed, apportioned and managed in such a manner as to enable all user sectors to gain equitable access to the desired quantity, quality and reliability of water. **Conservation** and other measures to manage demand shall be actively promoted as a preferred option to achieve these objectives
Principle 15: **Water quality and quantity are interdependent** and shall be managed in an integrated manner, which is consistent with broader environmental management approaches.
Principle 16: Water quality management options shall include the use of **economic incentives and penalties to reduce pollution**; and the possibility of irretrievable environmental degradation as a result of pollution shall be prevented.
Principle 18: Since many land uses have a significant impact upon the water cycle, the regulation of land use shall, where appropriate, be used as an instrument to manage water resources within the **broader integrated framework of land use management.**
Principle 19: Any **authorisation to use** water shall be given in a timely fashion and in a manner which is clear, secure and predictable in respect of the assurance of availability, extent and duration of use. The purpose for which the water may be used shall not arbitrarily be restricted.
Principle 21: The development and management of water resources shall be carried out in a manner which limits to an acceptable minimum the **danger to life and property due to natural or manmade disasters**.

LIST OF 13 PRINCIPLES AND OBJECTIVES MOST RELEVANT TO EUTROPHICATION MANAGEMENT:
Water institutions
Principle 23: Responsibility for the development, apportionment and management of available water resources shall, where possible and appropriate, be delegated to a catchment or regional level in such a manner as to **enable interested parties to participate**.
Water services
Principle 25: The right of all citizens to have access to **basic water services** (the provision of potable water supply and the removal and disposal of human excreta and wastewater) necessary to afford them a healthy environment on an equitable and economically and environmentally sustainable basis shall be supported.
Principle 27: While the provision of water services is an activity distinct from the development and management of water resources, **water services shall be provided in a manner consistent with the goals of water resource management**.

ANNEXURE E

The roles of the National Water Act, 1998 (Act No. 36 of 1998) and the Water Services Act, 1997 (Act No. 108 of 1997) in eutrophication management.

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The roles of the National Water Act, 1998 (Act No. 36 of 1998) and the Water Services Act, 1997 (Act No. 108 of 1997) in eutrophication management.

NATIONAL WATER ACT, 1998 (ACT NO. 36 OF 1998):

Although no mention is made of nutrient enrichment in the NWA (36:1998), there are several features to the Acts that merit the inclusion of eutrophication considerations. These include:

- **The National Water Resource Strategy:** The NWA (36:1998) requires the progressive development, after consultation with society at large, of a National Water Resource Strategy (NWRS). The NWRS provides the framework for the integrated water resource management for the country as a whole. It also provides the framework within which water will be managed at regional or catchment level, in defined Water Management Areas (WMAs). The NWRS, which must be formally reviewed in five yearly cycles, is binding on all authorities and institutions exercising powers or performing duties under the Act. Nutrient management considerations should form part of the NWRS.
- **Catchment Management Strategies:** The NWA (36:1998) devolves responsibility to Catchment Management Agencies (CMAs) to progressively develop Catchment Management Strategies (CMSs) for the water resources within their jurisdiction. All CMSs must be in harmony with the NWRS and set principles for allocating water to existing and prospective users, taking into account all matters relevant to integrated water resource management in a particular WMA. Nutrient management strategies should form part of all CMSs.
- **A national Classification System:** The NWA (36:1998) calls for the development of a system to classify the nation's water resources and, thus, requires guidelines and procedures for determining different classes of water resources. The system for classifying water resources may establish guidelines and procedures for determining different classes of water resources; establish procedures for determining the Reserve; establish procedures which are designed to satisfy the water quality requirements of water users, as far as is reasonably possible, without significantly altering the natural water quality characteristics of the resource; set out water uses for instream or land-based activities which activities must be regulated or prohibited in order to protect the water resource; and provide for such other matters relating to integrated water resource management. Government is required to classify all, or part of, water resources considered to be significant. Once a class has been determined, it is binding on all authorities and institutions, when exercising any power or performing any duty under the Act. Since anthropogenic eutrophication is an impediment to achieving the class, due consideration should be given to nutrient enrichment and the trophic status of specific waterbody types (*e.g.,* rivers, wetlands, reservoirs, lakes and estuaries).
- **The Reserve:** This is a volume of water that needs to be maintained for two purposes. The basic human needs reserve provides for the essential needs of individuals served by the water resource in question and includes 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. The Reserve refers to both the quantity and quality of the water in the resource, and will vary depending on the class of the water resource. Government is required to determine the Reserve for all or part of any significant water resource. Once the Reserve has been determined for a water resource it is binding on all authorities and institutions, when exercising any power or performing any duty under the Act. Eutrophication issues should form a strong consideration on the assessment of the Reserve.

- **Resource Quality Objectives:** Government is required to determine Resource Quality Objectives[125] (RQOs) for all, or part of, water resources considered to be significant. The RQOs will vary depending on the class of the water resource. The purpose of RQOs is to establish clear goals relating to the quality of the relevant water resources. Once RQOs have been determined they are binding on all authorities and institutions, when exercising any power or performing any duty under the Act. RQOs should give due consideration to nutrient enrichment and the trophic status of specific waterbody types (*e.g.,* rivers, wetlands, reservoirs, lakes and estuaries).
- **Pollution prevention:** The NWA (36:1998) 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 CMA 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. Anthropogenic eutrophication, amongst others, is the result of nutrient pollution, and its management should be incorporated into pollution control considerations.
- **Water use authorisation:** The NWA (36:1998) requires all water uses to be permissible and to comply with the conditions of the entitlement, including any Waste Discharge Standards (WDSs) that may relate to the combating of eutrophication, specified in Municipal Approvals, if relevant; or an Authorisation issued prior to 20 August 1996 to an ELU; or the applicable General Authorisation; or the water use Licence in question; or an alternative authorisation, if dispensing with the requirement for a licence to be issued under the NWA (36:1998). Additionally, the Act also enables the publication of a number of water quality management related regulations, which includes prescribing WDSs.
- **Regulations:** As enabling legislation, the NWA (36:1998) supports the development and publication of a variety of regulations, which deals with a range of aspects that may or should be related to the management of eutrophication (**Annexure F**). These provisions include prescribing the extent of water use; the monitoring, measurement and recording of water use; various requirements in relation to waterworks; regulation or prohibiting activities in order to protect water resources; waste standards; management practices; procedures for the allocation of water by means of public tender; and procedures, and the contents of assessments of the likely effect of proposed licences on resource quality.
- **Water pricing:** The NWA (36:1998) acknowledges the polluters-pay principle and, through the application of a system of waste discharge charges, including charging for nutrients, aims to-
  - promote the ecologically sustainable development and efficient use of water resources;
  - promote the internalisation of environmental externalities by impactors;
  - create financial incentives for dischargers to reduce waste and use water resources in a more optimal way; and
  - recover the costs of mitigating the impacts of waste discharges on water quality.
- **Water resource information management systems:** The NWA (36:1998) requires government to establish national information systems on the quantity and quality of all water resources. Eutrophication management issues and indicators should be included on any such developed information system(s) at both national and WMA (or sub-catchment) levels.

WATER SERVICES ACT, 1997 (ACT NO. 108 OF 1997)

Overlap between the WSA (108:1997) and the NWA (36:1998) exists to some extent, principally to ensure seamless integration, albeit that cooperative governance challenges frequently exist. Although mention of nutrient enrichment is not made in the WSA (108:1997) either, there are also several features to the WSA (108:1997) that merit the inclusion of eutrophication considerations.

- **National norms and standards:** The WSA (108:1997) enables the Minister of Water and Sanitation to prescribe national standards, *inter alia,* relating to-
  - the provision of water services;
  - the quality of water discharged into any water services or water resource system;
  - the effective and sustainable use of water resources for water services;
  - the nature, operation, sustainability, operational efficiency and economic viability of water services; and
  - requirements for persons who install and operate water services works.
- **Water Services Development Plans:** As part of the process of preparing Integrated Development Plans (IDPs), the WSA (108:1997) compels WSAs to develop Water Services Development Plans (WSDPs) for the water resources and services within their area. The contents of the WSDP*, inter alia,* relates to existing and expected future industrial effluent disposal; water sources to be used and the quantity of water to be discharged into each source; and the estimated capital and operating costs associated with the operation, maintenance, repair and replacement of existing and future infrastructure. Poorly operated and maintained WwTWs are sources of excessive nutrient enrichment. Nutrient management strategies should form part of all WSDPs.
- **Municipal approvals:** In terms of the WSA (108:1997), no person may dispose of industrial effluent in any manner other than that approved by the Water Services Provider (WSPs), nominated by the WSA having jurisdiction in the area in question. Additionally, the Act also enables the publication of compulsory national standards, *inter alia*, relating to– the quality of any wastewater being discharged into any water services or water resource system; and the effective and sustainable use of water resources for water services. Anthropogenic eutrophication, amongst others, is the result of nutrient pollution, and its management should be incorporated into pollution control considerations.
- **Water services information management systems:** The WSA (108:1997) requires government to establish national information systems on water services. Eutrophication management issues and indicators should be included on any such developed information system(s).

ANNEXURE F

Enabling provisions in the National Water Act, 1998 (Act No. 36 of 1998) and Water Services Act, 1997 (Act No. 108 of 1997) for making regulations or for prescribing compulsory national standards, which can be employed to enhance the control and management of anthropogenic eutrophication.

ANNEXURE F

Enabling provisions in the National Water Act, 1998 (Act No. 36 of 1998) and Water Services Act, 1997 (Act No. 108 of 1997) for making regulations or for prescribing compulsory national standards, which can be employed to enhance the control and management of anthropogenic eutrophication.

NATIONAL WATER ACT, 1998 (ACT NO. 36 OF 1998):

In cases where the enabling legislation allows for the making of regulations that could assist with the management of anthropogenic eutrophication, but such regulations do not exist, consideration must be given to the development and publication of such regulations.

In cases where regulations do exist, a re-evaluation can be considered of the suitability and/or effectiveness of those measures that relate to the management of anthropogenic eutrophication – specifically also their suitability to assist with the realisation of the Eutrophication Management Goal.

The table below lists those regulations under Section 26 of the NWA (36:1998), which could, or should be employed to enhance the control and management of anthropogenic eutrophication. Other provisions for making regulations under the NWA (36:1998), which are of a more general nature, or which mostly relate indirectly to the management of eutrophication, were not further considered here.

Regulations that are made under Section 26 of the NWA (36:1998) may-

- differentiate between different water resources and/or different water resource Management Classes (MCs);
- differentiate between different geographical areas; and
- create offences and prescribe penalties.

When making regulations, the following must be considered:

- to promote the economic and sustainable use of water;
- to conserve and protect water resources or, instream and riparian habitats;
- to prevent wasteful water use;
- to facilitate the management of water use and waterworks;
- to facilitate the monitoring of water use and water resources; and
- to facilitate the imposition and recovery of charges.

Relevant provisions, as per the National Water Act, 1998 (Act No. 36 of the 1998):	
Section/ Provision	**Context and potential application to enhance the efficacy of eutrophication management**
S.26(1) The Minister of Water and Sanitation may make regulations–	
(a) ***"limiting or restricting*** *the purpose, manner or extent of* ***water use****"*;	*Context* **To regulate (limit or restrict) particular water uses, including the discharge of water containing waste or the disposal of waste, with respect to purpose, manner of use and extent.**

Section/ Provision	Context and potential application to enhance the efficacy of eutrophication management
	Application ▶ This provision can be utilised to apply limiting or restrictive measures to water uses that potentially contribute to anthropogenic eutrophication; ▶ It may be possible to apply this provision to improve the regulation of ELUs, as an alternative to compulsory licensing; and ▶ A draft regulation was published under the NWA (36:1998) [GN R.1188 in GG 29413 of 1 December 2006]: Draft regulations for the use of water for rec*reational purposes, generally and in respect of a government waterworks and surrounding state-owned land*.
(d) *"prescribing the **outcome or effect which must be achieved** by the installation and operation of any **waterwork"***;	*Context* **To prescribe performance criteria for any waterwork, including a government waterwork, *i.e.,* any borehole, structure, earthwork or equipment installed or used for, or in connection with water use.** *Application* ▶ The performance targets can be selected and formulated to benefit eutrophication management and to improve the trophic status of selected receiving reservoirs and/or other water resources; ▶ A waterwork may include WwTWs; and ▶ No such regulations have been published.
(e) *"regulating the design, **construction**, installation, operation and maintenance of any **waterwork**, where it is necessary or desirable to monitor any water use or to protect a water resource"*;	*Context* **To prescribe minimum requirements for the establishment, operation and maintenance of any waterwork, including a government waterwork, *i.e.,* any borehole, structure, earthwork or equipment installed or used for, or in connection with water use.** *Application* ▶ The minimum requirements can be selected and formulated to benefit eutrophication management and to improve the trophic status of selected receiving reservoirs and/or other water resources; ▶ A waterwork may include WwTWs; and ▶ No such regulations have been published.
(f) *"requiring **qualifications** for and registration of persons authorised to design, construct, install, operate and maintain any **waterwork**, in order to protect the public and to safeguard human life and property"*;	*Context* **To prescribe minimum qualifications for persons, in connection with the establishment, operation and maintenance of any waterwork, including a government waterwork, *i.e.,* any borehole, structure, earthwork or equipment installed or used for, or in connection with water use.** *Application* ▶ This provision can be utilised to prescribe minimum qualifications for persons that establish, operate and maintain WwTWs. These qualifications can be selected and formulated to benefit eutrophication management; ▶ GN R.2834 in GG 10088 of 27 December 1985]: Regulations for the erection, enlargement, operation and registration of water care works, published under Section 26 of the WA (54:1956), or any relevant regulation meant to replace it, published under the WSA (108:1998) or NWA (36:1998); and ▶ Refer to S.9(1)(e), WSA (108:1997).

Section/ Provision	Context and potential application to enhance the efficacy of eutrophication management
(g) ***"regulating or prohibiting** any **activity** in order to protect a water resource or instream or riparian habitat"*;	*Context* **To regulate or prohibit land and/or water use activities in order to protect the resource quality and to give effect to RDMs.** *Application* ▶ This provision can be utilised to regulate (see S.26(1)(a) above) and/or to prohibit activities that can cause excessive nutrient-loading in sensitive or stressed areas; ▶ [GN R704 in GG 20119 of 4 June 1999]: Regulations on the use of water for mining and related activities, aimed at the protection of water resources, exist, and is currently being revised; and ▶ A draft regulation was published under the NWA (36:1998) [GN R.1188 in GG 29413 of 1 December 2006]: *Draft regulations for the use of water for recreational purposes, generally and in respect of a government waterworks and surrounding state-owned land*.
(h) *** *"prescribing **waste standards** which specify the quantity, quality and temperature of waste which may be discharged or deposited into or allowed to enter a water resource"*;	*Context* **To prescribe uniform WDSs, which specify nutrient loads and/or concentrations in waste disposed of and water containing waste discharged to surface water resources.** *Application* ▶ This provision can be utilised to prescribe updated uniform WDSs for nutrients, which inter alia give effect to RDMs; ▶ Although draft regulations have been prepared, no such regulations have been finalised or published; and ▶ [GN R.991 in GG 9225 of 18 May 1984]: General and Special Standards for the purification of Wastewater or Effluent, published under the previous Act, have not been repealed.
(i) *** *"prescribing the outcome or effect which must be achieved through **management practices** for the treatment of waste, or any class of waste, before it is discharged or deposited into or allowed to enter a water resource"*;	*Context* **To prescribe BMPs, BPGs, or portions thereof, which stipulate intermediate and/or end-results that must be achieved before waste is disposed of, or before water containing waste is discharged, or before point and/or diffuse sources of pollution are allowed to enter water resources.** *Application* ▶ This provision can be utilised to prescribe eutrophication management practices; and ▶ GN R704 in GG 20119 of 4 June 1999: Regulations on the use of water for mining and related activities aimed at the protection of water resources exists and is currently being revised.
(j) *** *"requiring that **waste discharged or deposited** into or allowed to enter a water resource be **monitored** and analysed, and prescribing methods for such monitoring and analysis"*;	*Context* **To require monitoring, and to prescribe methods for monitoring and analysis, of waste being disposed of, or water containing waste being discharged into, or allowed to entering, water resources.** *Application* ▶ This provision can be utilised to compel water users, who contribute to excessive nutrient-loading, to monitor the quality of their waste and/or water containing waste, and to regularly enter such data into a common information management system, such as IRiS. The availability of such e-data will make it possible to easily analyse information that can help with the management of eutrophication; and ▶ No such regulations have been published.

Section/ Provision	Context and potential application to enhance the efficacy of eutrophication management
(n) *"prescribing procedures for the* ***allocation of water*** *by means of public tender or auction"*; and	*Context:* **To prescribe methodologies for the allocation of water quality on the open market.** *Application:* ▶ This provision can be considered for allocating available water quality for nutrients on the open market; and ▶ No such regulations have been published for water quality.
(o) *"prescribing– (i) procedures for obtaining; and (ii) the required contents of,* ***assessments*** *of the likely* ***effect which any proposed licence may have*** *on the quality of the water resource in question"*.	*Context:* **To prescribe assessment methodologies that must be followed by proponents who are applying for water use authorisations in order to quantify the expected impacts on resource quality.** *Application:* ▶ This provision can be utilised to compel water users to investigate and report on the potential effects, associated with the disposal of waste and/or discharge of water containing waste, as proposed. This may include an assessment of available water quality, nutrient-loading and whether effect will be given to RDM and/or RWQOs/ WQPLs; and ▶ No such regulations have been published.

*** **Regulations may contain general provisions applicable to all waste; and/or specific provisions applicable to waste with specific characteristics.**

WATER SERVICES ACT, 1997 (ACT NO. 108 OF 1997)

In cases where the enabling legislation allows for the making of regulations or for prescribing compulsory national standards that could assist with the management of anthropogenic eutrophication, but such regulations or compulsory national standards do not exist, consideration must be given to the development and publication of such regulations or compulsory national standards.

In cases where regulations and or compulsory national standards do exist, evaluation of the suitability and/or effectiveness of those measures can be considered in relation to the management of anthropogenic eutrophication – specifically also their suitability to assist with the realisation of the Eutrophication Management Goal.

The table below lists those compulsory national standards that can be prescribed under Section 9(1) of the WSA (108:1997), which could, or should be employed to enhance the control and management of anthropogenic eutrophication. Other provisions for making regulations under the WSA (108:1997), which are of a more general nature, or which mostly relate indirectly to the management of eutrophication, were not further considered here.

The compulsory national standards that are prescribed under Section 9(1) of the WSA (108:1997) may differentiate between–

- different users of water services; and
- different geographic areas, taking into account among other factors the socio-economic and physical attributes of each area.

In prescribing compulsory national standards, the Minister of Water and Sanitation must consider–

- the need for everyone to have a reasonable quality of life;
- the need for equitable access to water services;
- the operational efficiency and economic viability of water services;

- any norms and standards for applicable tariffs for water services;
- any other laws or any standards set by other governmental authorities;
- any guidelines recommended by official standard-setting institutions;
- any impact which the water services might have on the environment; and
- the obligations of the National Government as custodian of water resources.

Relevant provisions, as per the Water Services Act, 1997 (Act No. 108 of the 1997):

Section/ Provision		Context and potential application to enhance the efficacy of eutrophication management
S.9(1)		**The Minister of Water and Sanitation may prescribe compulsory national standards relating to–**
S.9(1)(a) *"the **provision of water services**";*	*Context*	**To prescribe compulsory national standards for the provision of water supply services,** *i.e.,* the abstraction, conveyance, treatment and distribution of potable water, water intended to be converted to potable water, or water for commercial use, but not water for industrial use, **and sanitation services,** *i.e.,* the collection, removal, disposal or purification of human excreta, domestic wastewater, sewage, and effluent resulting from the use of water for commercial purposes**.**
	Application	▶ This provision can be utilised to apply specific standards to the provision of sanitation services, including controlling objectionable substances, grey water disposal and the use of effluent return-flows, that may affect anthropogenic eutrophication; and ▶ A regulation was published under the WSA (108:1997) [GN R.509 in GG 22355 of 8 June 2001]: Regulations *relating to compulsory national standards and measures to conserve water*.
S.9(1)(b) *"the **quality of water** taken from or **discharged into any water services or water resource system**";*	*Context*	**To prescribe compulsory national standards for return-flow water, being discharged into any water services or water resource system.**
	Application	▶ Water Services Authorities (WSAs) can also exercise control over the quantity and quality of effluent, including industrial effluent being discharged to water resources or to municipal sewer network systems; ▶ A regulation was published under the WSA (108:1997) [GN R.509 in GG 22355 of 8 June 2001]: *Regulations relating to compulsory national standards and measures to conserve water*.
S.9(1)(c) *"the **effective and sustainable use of water resources** for water services";*	*Context*	**To balance the need to protect water resources with the need to use water resources for the purpose of water services provision.**
	Application	▶ In order to conserve and to protect water resources, this provision can be utilised to promote water conservation, water demand management, water and effluent balance analysis and the determination of water losses, as well as wastewater recycling and reuse strategies, and to avoid, prevent and minimise water pollution; ▶ A regulation was published under the WSA (108:1997) [GN R.509 in GG 22355 of 8 June 2001]: *Regulations relating to compulsory national standards and measures to conserve water*.

<table>
<tr><th>Section/ Provision</th><th></th><th>Context and potential application
to enhance the efficacy of eutrophication management</th></tr>
<tr><td rowspan="2">S.9(1)(d) "the nature, operation, sustainability, operational efficiency and economic viability of water services";</td><td>Context</td><td>To ensure that water services related practices are sustainable, viable and efficient.</td></tr>
<tr><td>Application</td><td>▶ This provision can be utilised to prescribe compulsory national standards for basic sanitation, for basic water supply, for interruptions in the provision of water services, the quality of potable water, the repair of leaks, and the reporting of non-compliance; and
▶ A regulation was published under the WSA (108:1997) [GN R.509 in GG 22355 of 8 June 2001]: Regulations relating to compulsory national standards and measures to conserve water.</td></tr>
<tr><td rowspan="2">S.9(1)(e) "requirements for persons who install and operate water services works"; and</td><td>Context</td><td>To prescribe minimum qualifications for persons, in connection with the installation and operation of any water services works, i.e., of any reservoir, dam, well, pumphouse, borehole, pumping installation, purification work, sewage treatment plant, access road, electricity transmission line, pipeline, meter, fitting or apparatus built, installed or used by a water services institution to provide water services; water for industrial use; or to dispose of industrial effluent.</td></tr>
<tr><td>Application</td><td>▶ This provision can be utilised to prescribe minimum qualifications for persons, in connection with the installation and operation of any sewage treatment plant to provide sanitation services or to dispose of industrial effluent. These qualifications can be selected and formulated to benefit eutrophication management;
▶ GN R.2834 in GG 10088 of 27 December 1985]: Regulations for the erection, enlargement, operation and registration of water care works, published under Section 26 of the WA (54:1956), or any relevant regulation meant to replace it, published under the WSA (108:1998) or NWA (36:1998); and
▶ Refer to S.26(1)(f), NWA (36:1998).</td></tr>
<tr><td rowspan="2">S.9(1)(f) "the construction and functioning of water services works and consumer installations".</td><td>Context</td><td>To prescribe compulsory national standards for the establishment, operation and maintenance of any water services work, i.e. for a reservoir, dam, well, pumphouse, borehole, pumping installation, purification work, sewage treatment plant, access road, electricity transmission line, pipeline, meter, fitting or apparatus built, installed or used by a water services institution to provide water services; water for industrial use; or to dispose of industrial effluent; and any consumer installations, i.e. a pipeline, fitting or apparatus installed or used by a consumer to gain access to water services and includes a meter attached to such pipeline, fitting or apparatus.</td></tr>
<tr><td>Application</td><td>▶ This provision can be utilised to prescribe compulsory national requirements for the measurement or control of water that is supplied, for consumer installations other than meters, for pressure in reticulation system, etc.; and
▶ A regulation was published under the WSA (108:1997) [GN R.509 in GG 22355 of 8 June 2001]: Regulations relating to compulsory national standards and measures to conserve water.</td></tr>
</table>

ANNEXURE G

Summary of the purpose and nature of the National Eutrophication Monitoring Programme (NEMP).

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Summary of the purpose and nature of the National Eutrophication Monitoring Programme (NEMP).

Eutrophication monitoring in South Africa commenced in the early 1970's, where it was being done as *ad hoc* monitoring surveys and research projects supported by the Water Research commission (WRC) up to about 1985 [Toerien, et al., 1975]. In 1985 the Department of Water Affairs (DWA) initiated the first eutrophication-focused monitoring programme, the Trophic Status Project (TSP), which covered the 7 sensitive catchments mentioned in GN R.1567 (1980) and GN R.991 (1984), respectively. The TSP laid a solid foundation for the current National Eutrophication Monitoring Programme (NEMP), in that it highlighted the extent of the problem at a national scale and provided a database that was to be used for the design of the NEMP [DWAF, 2002].

After the implementation of the National Eutrophication Monitoring Programme (NEMP) in 2002, the Department also began regularly releasing data maps indicating the extent of eutrophication, thereby improving the knowledge about eutrophication in South Africa for an increasing number of sites.

The national objectives of the NEMP are to measure, assess and report regularly on-

- the current trophic status of South Africa's water resources;
- the nature of current eutrophication problems experienced in South Africa; and
- the potential for future changes in trophic status in South Africa's impoundments and rivers in a manner that will support strategic decisions in respect of their national management, be mindful of financial and capacity constraints, and yet be soundly scientific.

At the regional and local level, NEMP objective extend further to:

- Provide an early warning system for specific eutrophication-related problems;
- Assistance with the establishment of nutrient balance by identifying the local source of the problem; and
- Provide data that permits regional and national monitoring objectives to be achieved through local intervention.

The determinants that are measured as part of the NEMP, include chlorophyll-α, algae species, macro chemical variables such as Total Suspended Solids (TSS), ammonium (NH_4), nitrate and nitrite (NO_3 + NO_2), orthophosphate (PO_4), sulphate (SO_4), silica (Si), Total Alkalinity (TAL), Kjeldahl Nitrogen (KN), Total Phosphorus (TP), Electrical Conductivity (EC), pH, Temperature and Secchi disc depth. Visual monitoring of the algae blooms and macrophytes is also undertaken at the impoundments. The concentrations of selected inorganic attributes such as sodium, chloride, magnesium, potassium and sulphate are also included.

NEMP samples are to be collected fortnightly or monthly at the dams, lakes and rivers. The waterbody is then assigned a trophic status as a description of the quality for the purposes of describing the stage at which the eutrophication process is at.

Until recently, there were over 380 registered sites and 90 of these being river sites. In 2021, the NEMP monitored 24 dams and 9 rivers (dam inlets) - this being due to various challenges including the 2018 financial crisis, limited laboratory capacity and lack of samplers to assist with implementation.

The NEMP is an essential component of satellite monitoring, *e.g.,* CyanoLakes. Without confirmation of what is happening at the surface, the satellite data can be very misleading, especially when the water is turbid.

ANNEXURE H

Potential legislative amendments, necessary to improve eutrophication management.

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Potential legislative amendments, necessary to improve eutrophication management.

The following potential legislative amendments and reviews are proposed in this document. These changes are regarded as necessary to address anomalies or shortcomings, or to improve and strengthen certain statutory provisions:

RECOMMENDED LEGISLATIVE AMENDMENT	NOTES	REFERENCE *(page #)*
1. Amendment to allow reclassification of the Water Resource Class.	If the receiving water resource does not have enough allocable water quality to assimilate waste without exceeding the RQOs, and if there are major socio-economic drivers behind a proposed new waste discharge, there may be a case to be made for reclassification of a water resource. In this case, it needs to be investigated whether a lower Water Resource Class, which might allow for socio-economic development opportunities to be implemented, may be more appropriate. In such a case, the full procedures required under the legislation for the determination of a Water Resource Class, RQOs and Reserve, including stakeholder consultation, will be applied. The converse is also true, that is, if the Water Resource Class is found to be inadequate for any reason, a higher Management Class might be applied, after appropriate investigation and consultation.	73
2. Amendment to allow for the declaration of protected water source areas	Currently, the NWA (36:1998) allows for only the prohibition of activities in a water source area. A legislative amendment would allow the Minister of DWS to declare a high yield water source area as protected. This would ensure that certain areas receive full protection. This may be required for an area to recover and rehabilitate itself or it may simply be required for ecological protection.	82
3. Amendment to extend the financial provisioning clause to all high-risk polluting sectors	The financial provisioning for site rehabilitation should extend to all industries that are deemed *"high-risk"* polluters. This will ensure that provision is made, whilst the industry is operational, and it will aid to avoid post facto actions, with the State carrying the risk.	109
4. Amendments as part of the development of a Non-Point Source (NPS) Strategy	Legislative amendments may be required and need to be investigated, as part of the development of a NPS Strategy for South Africa. These may relate to amendments of the definition of water use, the authorisation process; monitoring requirements; and the addition of provisions to allow for the identification of P and N vulnerable zones; and provisions requiring several diffuse source related interventions.	150
5. Amendments to allow for pollution taxes	The ambitions of the WDCS will be extended by the introduction of pollution taxes on *"input products"*, such as on herbicides and pesticides in line with **POLICY STATEMENT 6**: A life cycle view on nutrient-loading.	151
6. Amendment to allow for the categorisation of polluting industries, based on risk	There are limited human and financial resources available within government. In order to use these resources most effectively and to achieve the greatest impact, a targeted risk-based approach should be adopted. Under this approach, the potential significance of the impact of water pollution must inform the level of response or intervention from the state. Thus, areas of particular sensitivity will receive heightened attention, as will activities from which the pollution potential is of a particularly hazardous nature and areas where pollution is already extremely high.	152

RECOMMENDED LEGISLATIVE AMENDMENT	NOTES	REFERENCE (page #)
7. Amendment to allow for the publication of a Water Polluter Register	The publication of information is a useful tool towards incentivising responsible behaviour. In the South African context, the Green Drop certification system for municipalities has proven the regulatory value of the reporting and disclosure of information. A Water Polluter Register should be introduced to extend this reporting beyond municipalities to incentivize polluters to reduce their pollution. In this register, enterprises that are meeting best practice standards should be recognised, as should non-compliance by enterprises.	**153**
8. Amendment to allow for the promulgation of a Money Bill for the Waste Discharge Levy	The WDCS is based on the Polluter-Pays Principle and aims to promote the sustainable development and efficient use of water resources; internalise the environmental and social costs of using water; create financial incentives for water users to reduce waste and use water resources more optimally, and recover costs associated with impacts of waste discharges. It consists of two charges: a Waste Discharge Levy and a Waste Mitigation Charge. The Waste Mitigation Charge, provided for by the NWA (36:1998), is intended to cover the quantifiable administrative costs of implementing measures to mitigate the negative impacts of waste related discharges. The Waste Discharge Levy provides a disincentive to the discharge of wastewater and will be based on the rate of water utilisation as a means of disposing of waste. In order for the Waste Discharge Levy to be introduced, an amendment to the NWA (36:1998) is required to give the Minister permission to promulgate a Money Bill.	**152**
9. Amendments to allow for eco-labelling	The introduction of an eco-labelling scheme that acknowledges the water pollution related life cycle of goods and products will stimulate innovation as more sustainable products are invented; develop markets that cater to evolving consumer interests; create opportunities for education; create new value chains by establishing new networks of production; monitor water resource claims; influence consumer behaviour towards more water resource friendly products; promote economic efficiency in response to predefined standards; muster economic support for sustainability; and reallocate the costs of improving the trophic status of receiving water resources.	**154**
10. Amendment to allow for administrative penalties	Currently South Africa relies on criminal prosecution for addressing water quality violations, but such processes are slow and difficult, particularly in an overburdened criminal justice system. Criminal prosecution is dependent on evidence that proves the case beyond reasonable doubt, and the support of the South African Police Service and National Prosecuting Authority. Many of the players in the criminal justice system do not fully understand water legislation or the seriousness of environmental crimes, with the result that such violations do not draw serious penalties. This is a common problem in many countries, and as a result, many countries are moving towards administrative or civil penalty systems for environmental violations, with a criminal enforcement option retained for the worst environmental crimes. Certain activities that result in water pollution will still follow the criminal prosecution route, such as acts of vandalism.	**181**

ANNEXURE I

Quick Reference Table: Eutrophication Management Policy.

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STATEMENT #	POLICY STATEMENT	REFERENCE *(page #)*
Policy statements in support of the Chief Objectives for eutrophication management		
POLICY STATEMENT 1	Application of management instruments for environmental compliance in eutrophication management	67
POLICY STATEMENT 2	The Mitigation Hierarchy for decision-making on eutrophication	70
POLICY STATEMENT 3	The Differentiated Approach for the control of excessive nutrient-loading	73
POLICY STATEMENT 4	The application of the Precautionary Principle	75
POLICY STATEMENT 5	The Receiving Water Quality Objectives Approach applied to eutrophication management	76
POLICY STATEMENT 6	A life cycle view on nutrient-loading	78
POLICY STATEMENT 7	Incentive-based regulation	80
POLICY STATEMENT 8	Nature-based solutions	82
POLICY STATEMENT 9	The application of the Best Practicable Environmental Option	84
POLICY STATEMENT 10	Holistic eutrophication management	86
POLICY STATEMENT 11	Eutrophication management responsibility and accountability	88
POLICY STATEMENT 12	Monitoring	90
POLICY STATEMENT 13	Information management	92
POLICY STATEMENT 14	Water resource assessment and planning to inform decision-making	93
Policy statements in support of the Complementing Objectives for eutrophication management		
POLICY STATEMENT 15	Resourcing of eutrophication management	94
POLICY STATEMENT 16	Promotion of eutrophication-related research	95
POLICY STATEMENT 17	Transparency	96
POLICY STATEMENT 18	Technical capacity to take eutrophication management action	96
POLICY STATEMENT 19	Cooperative eutrophication management	98

ANNEXURE J

Quick Reference Table: Eutrophication Management Strategy.

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Quick Reference Table: Eutrophication Management Strategy.

CORE STRATEGIES					
Source Directed Management	Page 104	Resource Directed Management	Page 106	Remediation Directed Management	Page 109

OPERATIONAL STRATEGIES		
PLAN ↓	Assessment	Page 112
	Forward planning	120
	Goal setting	123
	Intervention planning	129
DO ↓	Best management practice	137
	Water use authorisation and conditional regulation	140
	Incentive-based regulation	152
CHECK ↓	International and transboundary status and trends monitoring and reporting	158
	Domestic status and trends monitoring and reporting	161
	Although the monitoring tools discussed in **TABLE 27** help to get a better understanding of related conditions that are either associated with eutrophication or that will help to improve eutrophication management efforts, a monitoring tool that applies to nutrient enrichment specifically has not yet been developed. Management performance monitoring and reporting	168
	Data acquisition and information management	171
ACT ↻	Retroactive action	176
	Enforcement	181
	Management review	183

SUPPORTING STRATEGIES					
Technical capacity building to give impetus to eutrophication management	Page 185	Research and technology development to address eutrophication-related challenges	Page 189	Collaboration and management participation	Page 192