South African National Water Quality Monitoring Programmes Series

National Eutrophication Monitoring Programme

Implementation Manual

Final Draft

Department of Water Affairs and Forestry

First Edition
2002

EXECUTIVE SUMMARY

Background

This manual was the primary deliverable of a Water Research Commission project to design and develop an implementation plan for a National Eutrophication Monitoring Programme (NEMP) for South Africa's water resources. Much eutrophication-related monitoring has been done in South Africa over the past three decades. However, there does not exist a coordinated effort that allows reporting on the nationwide status and trends of eutrophication. This manual describes the standardised implementation of eutrophication monitoring that addresses this shortcoming. The manual is primarily aimed at DWAF officials (and agents appointed by them) who will initialise, execute and sustain the NEMP at national, regional and local levels.

Not all parts of the manual are applicable to all parties. For this reason, the target readership is identified at the start of each chapter (and is indicated below in this summary).

Responsibility philosophy

A clear understanding of who has primary responsibility for the NEMP is critical for a good understanding of how this manual should be used. The National Water Act, No. 36 of 1998 specifically requires that national monitoring systems be established. DWAF has the primary responsibility for this. For a national monitoring system to be successful, it is necessary that individual local monitoring programmes be implemented. A local programme can refer to a single impoundment, river reach or canal. Regional programmes (covering Water Management Areas) may also be created.

Importantly, this manual defines the minimum design requirements (in respect of sampling variables, sampling frequency, choice of sampling sites, etc.) that DWAF must satisfy to meet the national objectives of the NEMP (defined below). DWAF has the primary responsibility for this.

However, this manual not only provides a national implementation process but one for regional and local implementation as well. Furthermore, it provides monitoring frameworks for addressing the following six local objectives for impoundments and rivers (except for establishing trophic status).

- Establishing trophic status (impoundments only);
- Early warning system - water treatment;
- Early warning system - blooms
- Early warning system - invasive macrophytes
- Early warning system - long term impacts

- Nutrient balance

These monitoring frameworks should be seen as *recommended* designs for local stakeholders. Because they address more demanding objectives, they necessarily require more intensive monitoring than that required for meeting the national objectives. However, they are intended to provide guidance to local stakeholders (to those who request it) on the appropriate design of local monitoring programmes. These are designs that

- address their local objectives, and
- are totally compatible with (indeed, go beyond) the minimum requirements for the NEMP.

This approach is intended to simplify the process of local monitoring programme design and create better buy-in to the NEMP because local objectives are also shown to be important.

However, DWAF will not automatically assume responsibility for such local programmes. This is particularly so if a local design is chosen that goes beyond the minimum requirements for the national programme. Exactly who has what responsibility will be subject to negotiation between DWAF and the local stakeholders. The final decision will then be recorded in a formal contract between the parties. This will also detail who will perform the various monitoring tasks (sampling, analysis, etc.).

> ***Typical idealistic scenario for initialisation of a local monitoring programme:***
> DWAF approaches a local stakeholder expressing interest in establishing a local eutrophication monitoring programme in an impoundment in which no such monitoring currently exists. DWAF indicates a willingness to be responsible (*i.e.* provide resources) to the extent of the minimum national requirements. The local stakeholder examines the recommended local design that meets its chosen local objectives. The local stakeholder agrees to provide the necessary resources for any monitoring that might be over and above the minimum national requirements. Details are negotiated, a contract is drawn up and monitoring starts.

Similarly, any regional monitoring programme that is implemented that addresses regional objectives will also need to be negotiated with the regional stakeholders.

Chapter 2: Eutrophication

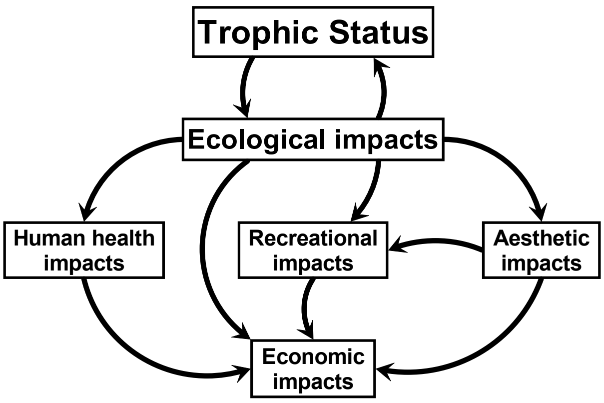
This chapter should be read by anyone wanting a brief summary of the causes, the impacts and the management of eutrophication.

Eutrophication is a major water resource problem in most industrialised countries [Walmsley, 2000]. Many South African impoundments exhibit high nutrient enrichment and eutrophication-related problems [van Ginkel, *et al.*, 2000]. However, most

Eutrophication is the process of excessive nutrient enrichment of waters that typically results in problems associated with macrophyte, algal and cyanobacterial growth.

impoundments in South Africa do not have regular eutrophication monitoring programmes. Eutrophication is of concern because it can have numerous negative impacts. These include ecological impacts (like deteriorating water quality and loss of biodiversity), aesthetic, recreational and human health impacts. All can have significant economic impacts.

Potential general negative impacts of eutrophication



Of particular concern is the lack of formal eutrophication management strategies for Water Management Areas or South Africa as a whole. It is imperative that these be developed as an integral part of the catchment management strategies associated with newly established catchment management agencies. Two DWAF reports lay a good foundation for the water quality component of catchment management strategies and should be carefully consulted [DWAF, 2000a; DWAF 2001a].

Chapter 3: National Implementation

This chapter should be used primarily by the National Coordinator for overall guidance on the implementation process of the NEMP at a national level.

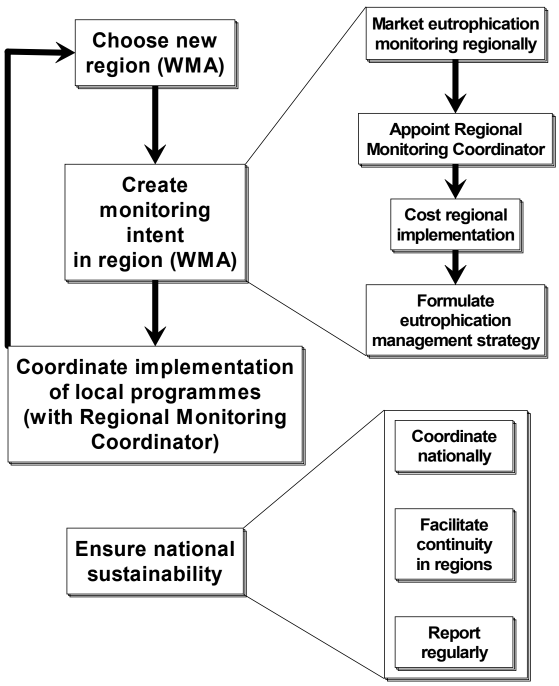
National Eutrophication Monitoring Programme DWAF National Objectives

To measure, assess and report regularly on
(1) the current trophic status,
(2) the nature of current eutrophication problems,
(3) the potential for future changes in trophic status
in South African impoundments and rivers
in a manner that will
support strategic decisions in respect of their national management,
be mindful of financial and capacity constraints, yet,
be soundly scientific.

(What are the eutrophication problems in South Africa, how bad are they and what are the likely future problems?)

A National Coordinator should be appointed who should champion, drive, manage and facilitate implementation of the NEMP using the general process illustrated in the adjacent figure.

National Eutrophication Monitoring Programme National Implementation Process (Tasks of National Coordinator)



While carrying out the national implementation process, the National Coordinator must take account of the following important issues.

- ★ On-going DWAF Water Resource Management restructuring;
- ★ Demonstrating early successes to create recognition and acceptance and hence further resource allocation and thus capacity creation;
- ★ Balancing top-down and bottom-up management approaches;
- ★ Anticipating problems experienced by other national programmes;
- ★ Creating awareness;

- ★ Creating and sustaining the necessary capacity (for sampling, analysis, etc.);
- ★ Database management and development to suit the needs of the NEMP;
- ★ Using (or adapting, if necessary) existing eutrophication monitoring programmes;
- ★ Capturing appropriate historical data (particularly to help establish baseline information);
- ★ Sustaining a commitment to good sampling and analytical techniques;
- ★ Initialising research that aims at improving the ability of the NEMP to address its objectives;
- ★ Defining a measurable implementation timetable for the NEMP over the coming years.
- ★ Regular revision of the national programme to ensure that the objectives are still being met.

When initialising a new local monitoring programme, the following minimum requirements should be met for each objective.

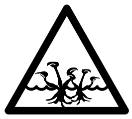
Table 1.1. Summary of minimum design requirements for meeting the national objectives.

For the national objective ...	... the minimum requirements are ...	Other useful variables are ...
Current trophic status (impoundments only)	At least every 2 weeks TP, chlorophyll *a*, sampled at dam wall or near abstraction point.	Secchi Depth, EC, pH, Temp, DO, TN, TSS.
Nature of current eutrophication problems	*Blooms*: Monthly visual monitoring near dam wall, abstraction point or where used for drinking purposes and, if detected, phytoplankton counts and genus identification. *Macrophytes*: Three monthly visual monitoring in potentially problematic locations (*e.g.* downwind) and, if detected, species identification and area affected.	*Blooms*: cyanotoxins (if counts high), geosmin.
Potential for future changes in trophic status	Annual land use statistics, runoff factors, nutrient balance, loads etc. and as for trophic status above (*i.e*. every 2 weeks, TP, chlorophyll *a*, etc. for validation).	

Implementation in the first few years should be restricted to the first two objectives (establishing the current trophic status and the nature of the problems). The more complex monitoring required for addressing the potential for future changes should be introduced later, if deemed necessary. However, in a few cases, such as Roodeplaat and Hartbeeshoek dams, intensive sampling programmes already exist which could possibly be adapted for predictive modelling with minimum effort.

The following table illustrates the local objectives whose local monitoring frameworks would address each of the three national objectives.

Table 1.2. Identification of the local objectives that would address each national objective.

National objective	Local monitoring frameworks that provide the necessary data	
Current trophic status	Establish the trophic status	
Nature of current eutrophication problems	Early warning system - water treatment	
	Early warning system - blooms	
	Early warning system - invasive macrophytes	
Potential for future changes in trophic status	Early warning system - long term impacts	

Chapter 4: Regional Implementation

This chapter should be used primarily by the Regional Monitoring Coordinator for guidance on the overall implementation process of the NEMP in a Water Management Area.

The objectives at regional (WMA) level address similar questions to the national level except they are focussed on the WMA. A regional monitoring programme is not automatically the responsibility of DWAF. As for local programmes, a regional programme should address regional and national objectives. It should ideally be a win-win situation and should be negotiated as such.

National Eutrophication Monitoring Programme
DWAF or CMA
Regional (Water Management Area) Objectives

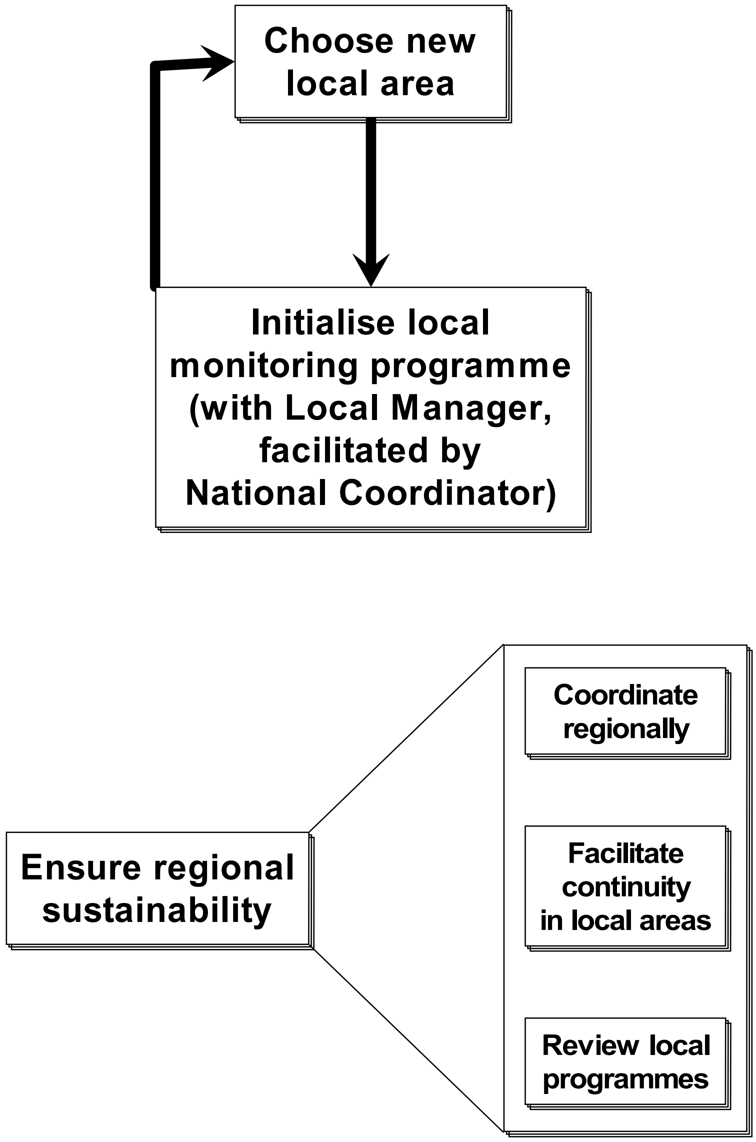
To measure, assess and report regularly on
(1) the current trophic status,
(2) the nature of current eutrophication problems,
(3) the causes of current nutrient enrichment, and
(4) the potential for future changes in trophic status
in impoundments and rivers in a Water Management Area
in a manner that will
support strategic decisions in respect of their regional management,
be mindful of financial and capacity constraints, yet,
be soundly scientific.
(What are the eutrophication problems in the WMA, how bad are they, what is causing them and what are the likely future problems?)

AND

Provide regional data that permit
national monitoring objectives to be achieved.
(What is the problem in South Africa, how bad is it and how is it changing?)

The Regional Monitoring Coordinator (typically a DWAF or catchment management agency representative) should facilitate the following general regional implementation process. The Regional Monitoring Coordinator also needs to carefully consider the kinds of issues noted above for the National Coordinator.

National Eutrophication Monitoring Programme
Regional Implementation Process
(Tasks of Regional Monitoring Coordinator)



Chapter 5: Local Implementation

This chapter should be used primarily by the Regional Monitoring Coordinator and the Local Manager for guidance on the overall implementation process of the NEMP in a local area (*e.g.* a single impoundment).

National Eutrophication Monitoring Programme
DWAF or CMA
Local Area Objectives

To measure, assess and report regularly on
(1) the current trophic status,
(2) the nature of current eutrophication problems,
(3) the causes of current nutrient enrichment, and
(4) the potential for future changes in trophic status
in impoundments and rivers in a local area
in a manner that will provide support
for decisions in respect of their local management and use,
be mindful of financial and capacity constraints, yet,
be soundly scientific.
(What are the eutrophication problems in the local area, how bad are they, what/who is causing them and what are the likely future problems?)
or
Provide an early warning system
for specified eutrophication-related problems.
(Is a serious local eutrophication problem about to occur?)
or
Establish a nutrient balance.
(What/who is causing the local problem?)

AND

Provide local data that permit
regional and national monitoring objectives to be achieved.
(What is the problem in the region, how bad is it and how is it changing?)

The Regional Monitoring Coordinator (and, if necessary, the National Coordinator) will first identify appropriate local objectives for the chosen local area in collaboration with a local stakeholder. The following table illustrates the context in which some objectives can be chosen.

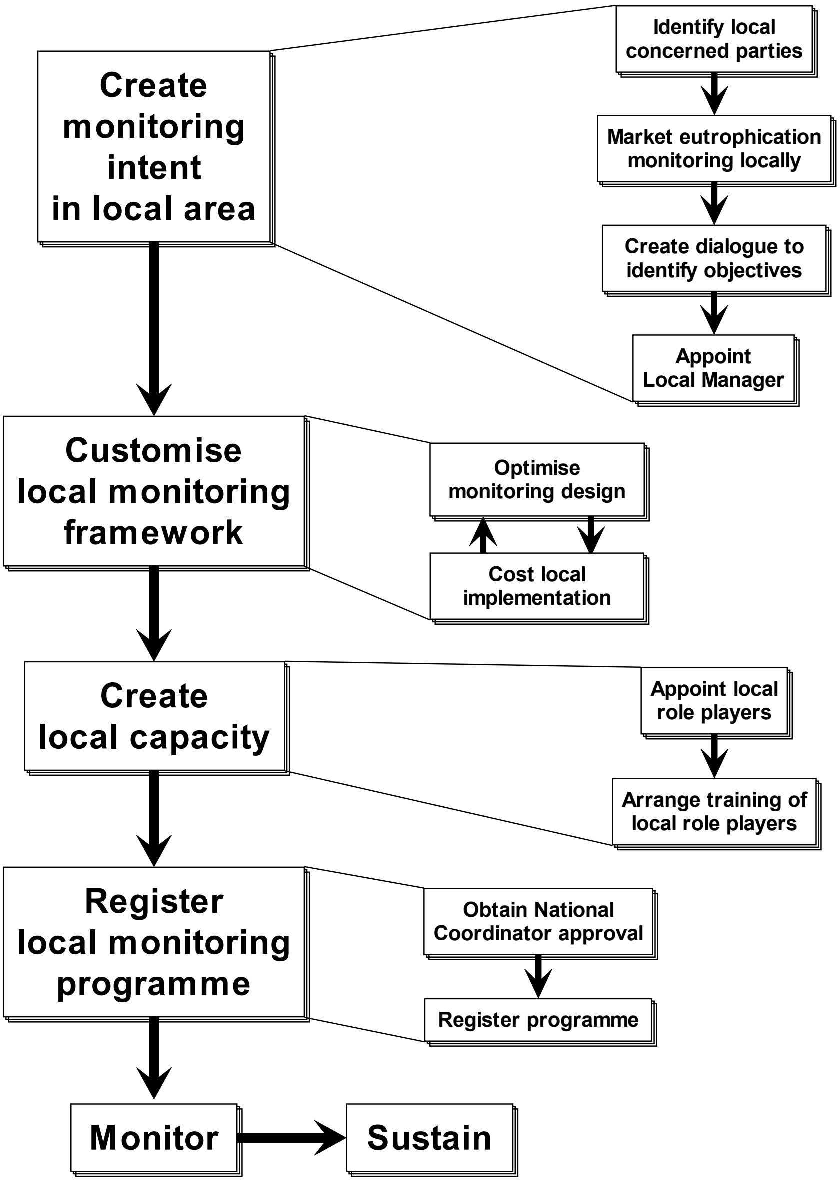
Table 1.3. Context of local area management or stakeholder objectives.

If the local manager or stakeholder is focussed on the following aspect of current or future eutrophication ...	***Then the specific monitoring objectives that can provide relevant information are ...***	
Extent	Establish trophic status	
Nature and extent	Early warning system: Water treatment *(reasons: avoid taste & odour & filter clogging problems)*	Short term
	Early warning system: Algal blooms *(reasons: avoid scums, odours, health risks due to direct use of raw water)*	
	Early warning system: Invasive macrophytes *(reasons: minimise water loss, ecological & recreational impacts)*	
Long term prediction	Early warning system: Future increase in trophic status *(reasons: mitigate or avoid future eutrophication related impacts)*	Long term
Causes	Nutrient balance	

They must then negotiate a local monitoring programme design with an appointed Local Manager representing a local stakeholder to the satisfaction of both parties. Use can be made of the recommended local monitoring frameworks if necessary.

The general local implementation process involves a series of steps, illustrated in the adjacent figure.

National Eutrophication Monitoring Programme
Local Implementation Process
(Local tasks of Regional Monitoring Coordinator)



Chapter 6: Local Monitoring Frameworks

> This chapter should be used primarily by the Regional Monitoring Coordinator and the Local Manager for designing detailed monitoring programmes for a local area (*e.g.* a single impoundment) once the monitoring objectives have been identified.

There are many generic factors to consider when designing a local monitoring programme. These include overlapping with existing (though appropriately designed) monitoring programmes as much as possible. They also include the selection of sites for sampling and visual monitoring, sampling frequency, quality control and data assessment. These are described in some detail to provide general guidance (to those requiring it) for designing the local programme.

A recommended monitoring framework has also been developed for each of the local monitoring objectives in **Table 1.3**. These should be seen as broadly-based generic recommendations that should be used as a point of departure in the design of a local monitoring programme. The trophic status objective applies only to impoundments though the others apply to impoundments and rivers.

Chapter 7: Procedure Specifications

> This chapter should be used primarily by the Regional Monitoring Coordinator and the Local Manager for defining the procedures to be followed in a local monitoring programme.

Ideally, a quality assurance plan should be developed for each local monitoring programme. This plan should have clear objectives, that, generically, ensure that the monitoring objectives are achieved while minimising the likelihood of quality problems occurring. Recommendations on the structure and content of such a plan are given.

Descriptions are provided for procedures for on-site measurements including visual area estimation and measuring Secchi disk depth. Sampling procedures using a standard 5m hosepipe, subsurface grab and surface grab samples are also described and illustrated. Sample preparation for chlorophyll *a* measurements using a portable hand filter apparatus is also described. The sample preservation methods used by DWAF are described and recommendations made for laboratory and on-site analytical procedures.

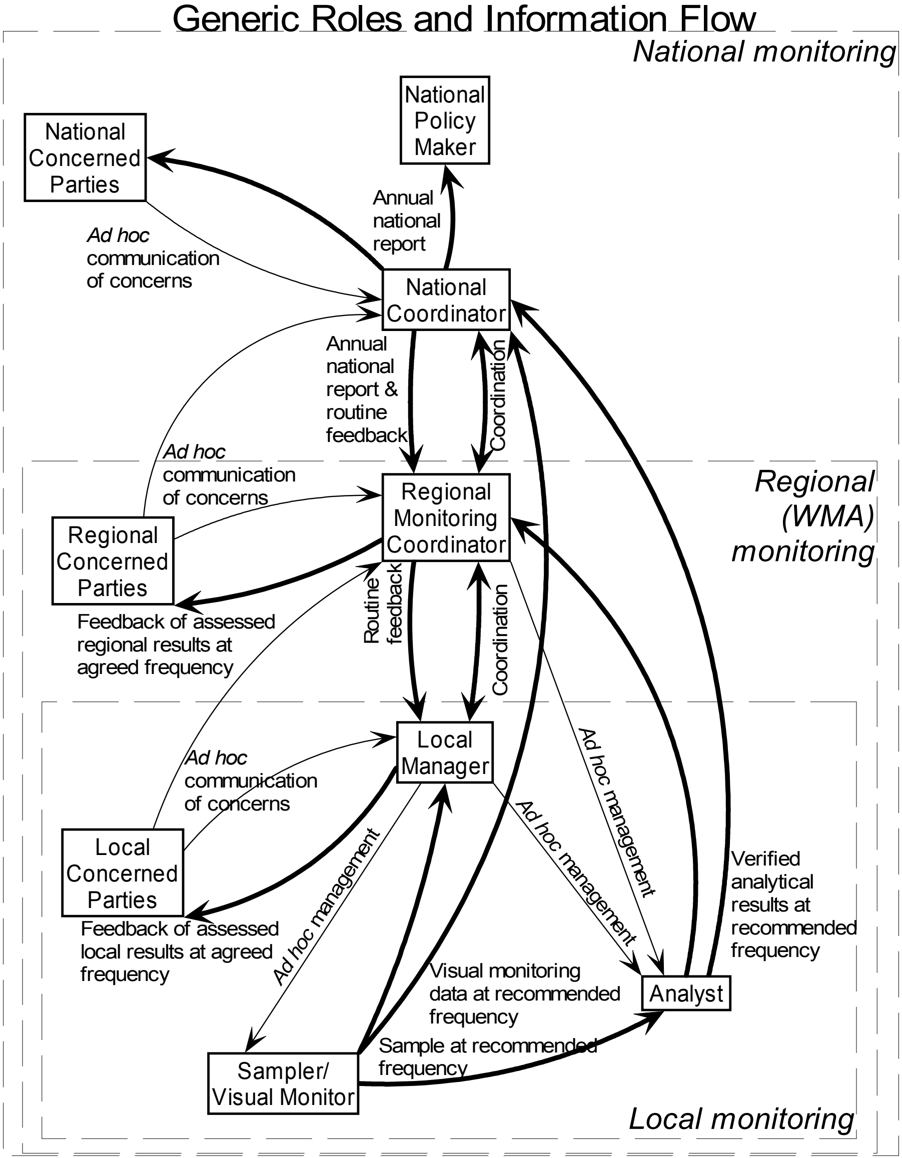
Each sampling and analysis procedure that is recommended is defined. The primary purpose of this is to ensure nationwide standardisation while being as cost-effective as possible.

Chapter 8: Roles and Responsibilities

This chapter should be used by any role player to establish the tasks required to be implemented by any of the role players in the NEMP.

Generic monitoring roles and tasks are identified as well as the information flow between role players. The exact nature of the local roles depends on the objectives.

National Eutrophication Monitoring Programme
Generic Roles and Information Flow



Chapter 9: The Business of Monitoring

> This chapter should be used by the National Coordinator and the Regional Monitoring Coordinator for guidance on some of the general business principles relevant to successful implementation of the NEMP.

Implementing a national, regional or local monitoring programme should be seen as a business. A product (the information product or report of the monitoring programme) needs to be marketed and 'sold' to a potentially wide variety of local stakeholders who would like to see a return that is proportional to their individual level of investment. Besides direct funding from DWAF, other potential funding sources for the NEMP vary from local, regional, national to international.

A spreadsheet-based costing model for NEMP implementation is available from DWAF to facilitate accurate costing at local, regional and national levels. It permits distinction between multiple resource providers. It allows specification of operating and capital costs and human resource costs (using hours and hourly rates) for such tasks as sampling, analysis, capacity building, database management, coordination etc.

Based on a series of simple assumptions, it then provides various summary statements of five yearly cost estimates for a single local programme. If average costs are used, and the number of local programmes in a region or nationally is specified, similar five yearly cost estimations can be obtained for a regional or national programme.

The advantages of the facility are as follows.

- ❑ The various resource providers (local, regional and national) can jointly optimise parameters (such as the number of sampling sites and the variables to be analysed) to ensure that total costs are within reasonable limits.
- ❑ Costs incurred by all resource providers can be distinguished so all are aware of what the others are contributing, creating total transparency.
- ❑ Since human resource hours are also recorded, each resource provider knows what time commitments are necessary.

The importance of creating and sustaining commitment to the NEMP is also addressed. Particular emphasis is given to the importance of sound sampling and analysis. It is proposed that a reward system be seriously considered. Reward systems in general are discussed briefly. Some generic suggestions are also presented concerning how a reward system could be introduced into the NEMP.

The importance of a sound marketing strategy is also noted. It is recommended that a professional marketing person or organisation be employed to develop an appropriate marketing strategy and implement specific marketing drives.

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Dr RD Walmsley	Mzuri Consultants

CONTENTS

LIST OF ABBREVIATIONS

National
Eutrophication
Monitoring
Programme

AGIS	Agricultural Geographical Information System
ARM	Adaptive Resource Management
Chl *a*	Chlorophyll *a*
CMA	Catchment Management Agency
DEAT	Department of Environmental Affairs and Tourism
DO	Dissolved Oxygen
DOH	Department of Health
DSR	Driving Force - State - Response
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
GEAR	Growth, Employment And Redistribution
I&AP	Interested and Affected Party
IWQS	Institute for Water Quality Studies
NAEBP	National Aquatic Ecosystem Biomonitoring Programme
NEMP	National Eutrophication Monitoring Programme
NGDS	National Growth and Development Strategies
NMMP	National Microbial Monitoring Programme
NTU	Nephelometric Turbidity Units
NWRS	National Water Resources Strategy
QA	Quality Assurance
QC	Quality Control
RDM	Resource Directed Measures
RHP	River Health Programme
RQO	Resource Quality Objectives
SAPIA	South African Plant Invaders Atlas
SD	Secchi Disk depth
SoE	State of the Environment
TN	Total nitrogen
TP	Total phosphorus
TSS	Total Suspended Solids
WHO	World Health Organisation
WMA	Water Management Area
WMS	Water Management System
WRC	Water Research Commission
WUA	Water User Association

GLOSSARY

Algae. Chlorophyll-bearing organisms in the plant subkingdom Thallobionta. They may be free-floating or attached to structures such as rocks or other submerged surfaces.

Allochthonous. Pertaining to organisms or organic sediments in a given ecosystem that originated in another system.

Anaerobic. A condition in which no dissolved oxygen is present.

Anthropogenic. Resulting from the pressure of human activities.

Biodiversity. Biodiversity comprises composition, structure, and function of ecosystems. Composition is the identity and variety of elements in a collection, and includes species lists and measures of species diversity and genetic diversity. Structure is the physical organization or pattern of a system, from habitat complexity as measured within communities to the pattern of patches and other elements at a landscape scale. Function involves ecological and evolutionary processes, including gene flow, disturbances, and nutrient cycling.

Biomonitoring. The gathering of biological information in both the laboratory and the field for the purpose of making an assessment or decision or for determining whether quality objectives are being met.

Biota. Animal and plant life characteristic of a given region.

Bloom. A noticeable change in colour of water caused by excessive algal growth.

Blue-green algae. See ***Cyanobacteria***.

Catchment. The area that receives the rain that flows into a particular watercourse.

Catchment Management Agency. A Water Management Institution which is a statutory body governed by a board representing the interests of water users, potential water users, local and provincial government and environmental interest groups. It manages water resources within a defined Water Management Area.

Chlorophyll. The green pigment found in plants responsible for photosynthesis.

Conservative Variable. A substance or material whose amount in a water body remains constant with time although its concentration may decrease due to dilution or increase due to evaporation. Non-reactive chemicals like sodium and chloride are good examples.

Cultural Eutrophication. Eutrophication resulting from human (anthropogenic) activities (such as excessive use of fertilisers and/or detergents).

Cyanobacteria. A large group of bacteria comprising unicellular and multicellular prokaryotes that use photosynthesis as their principal mode of energy metabolism. Also referred to as blue-green algae.

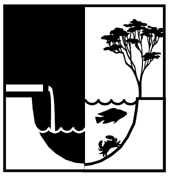
Cyanotoxins. Toxic substances (including cyclic peptides, alkaloids and lipopolysaccharides) produced by cyanobacteria as secondary metabolites.

Dam. 1. A barrier constructed to obstruct the flow of a watercourse and store water. 2. The water stored by the structure.

Destratification. The development of complete vertical mixing within a lake or reservoir that either partially or totally eliminates separate layers of temperature, plant or animal life.

Diatoms. (Bacillariophyta) A division of unicellular or colonial nonflagellate algae having delicately sculptured silica cell walls divided into two overlapping halves.

Diffuse-source Pollution. Pollution that comes from a wide area that is not easily quantifiable, such as fertilisers draining off farmlands or pollutants in the runoff from urban areas.



Ecological Integrity. The ability of an ecosystem to support and maintain a balanced, integrated composition of physico-chemical habitat characteristics, as well as biotic components, on a temporal and spatial scale, that are comparable to the natural state (*i.e.* unimpaired) characteristics of such an ecosystem. (High ecological integrity implies that the structure and functioning of an ecosystem are unimpaired by anthropogenic stresses.)

Ecosystem. The total community of living organisms and their associated physical and chemical environment.

Epilimnion. The upper level of water in a thermally stratified water body of relatively warm water in which mixing occurs as a result of wind action and convection currents. (Cf. Hypolimnion.)

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

Eutrophication. The process of nutrient enrichment of waters that results in problems associated with macrophyte, algal or cyanobacterial growth. See ***Cultural Eutrophication***.

Geomorphology. The study of the physical features of aquatic ecosystems and their relationship to catchment geology.

Geosmin. A metabolite produced in trace concentrations by certain cyanobacteria, algae and bacteria. It is released into water and soil where it imparts a typical earthy/muddy odour and taste. The odour and taste threshold for humans is extremely low (of the order of ng/ℓ).

Groundwater. Water found underground, typically supplying wells, boreholes, and springs.

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

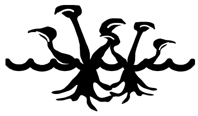
Hypolimnion. The lower level of water in a thermally stratified water body, characterised by a uniform temperature that is colder than that of other strata in the water body. (Cf. Epilimnion.)

Impoundment. The water body formed behind a weir or dam wall, which can be used for irrigation, flood control, domestic or industrial use etc.

Invertebrate. An animal lacking a backbone and internal skeleton.

Lake. A natural body of water surrounded by land.

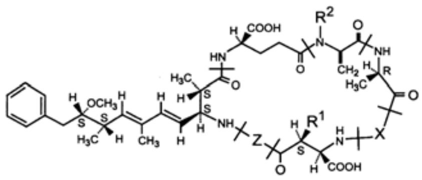
Macrophyte. A plant large enough to be seen by the naked eye, especially one associated with an aquatic habitat.



Water hyacinth

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

Microcystins. Cyclic peptide cyanotoxins produced by some cyanobacteria.



Microcystins are complex chemicals.

Natural Eutrophication. Eutrophication resulting from natural processes (like nutrient enrichment from the local geology and soils).

Non-conservative Variable. A substance or material whose amount in a water body can change with time irrespective of how much was originally added to the water. Reactive chemicals like phosphate or material that comprises living organisms like faecal coliforms and algae are examples.

Non-point Source Pollution. Pollution that comes from a diffuse source, such as runoff from a large agricultural area, that is usually difficult to quantify.

Nutrient. Substance that supports growth and reproduction. In the context of aquatic plants, these include nitrogen, phosphorus, carbon, silica and iron (among others).

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

Orthophosphate. The chemical species PO_4^{3-} in all the forms in which it binds to other chemical constituents. These can be inside solid particles, adsorbed on their surfaces or dissolved in water. When dissolved, this form of the nutrient phosphorus is readily available for use by plants.

Phytoplankton. See ***Plankton***.

Plankton. The large community of microorganisms that floats freely in the surface waters of oceans, seas, rivers and lakes. They are moved passively by wind, water currents, or waves, having little or no powers of locomotion themselves. The plant plankton (phytoplankton) includes many microscopic algae, particularly the diatoms. They form the basis of the food chain in water, being eaten by the animal plankton (zooplankton), which in turn provides food for fish.

Point-source Pollution. Pollution that comes from a single source that is usually easily quantifiable *e.g.* sewage works or factory.

Prioritisation. The process of establishing an order of things based on the degree to which they require special attention.

Quality Assurance. The implementation of all activities that minimise the possibility of quality problems occurring. These activities include (among others) training, instrument calibration and servicing, quality control, producing clear and comprehensive documentation, and so on.

Quality Control. The process of ensuring that recommended monitoring procedures are followed correctly by detecting and correcting quality problems when they arise, so that the accuracy of primary observations or measurements is (a) defined, (b) within acceptable limits and (c) recorded. These monitoring procedures are visual monitoring, sampling, sample preparation, sample preservation, sample analysis and data capture.

Riparian. Living or located on the banks of streams and rivers.

Runoff. Water that does not filter into soil but flows over the surface and into natural surface waters.

Sedimentation. The process by which suspended solids settle downwards.

Settlement. A permanently populated area of high population density.

Site-specific. Specific to a certain locality.

Spatial Variability. Change in some property in three-dimensional space at a specific time (*e.g.* change in temperature from the surface to the bottom of a water body).

Stratification. The formation of separate layers (for example, of temperature, plant or animal life) in a lake or reservoir.

Surface Water. Water above the ground surface in impoundments, lakes, dams and rivers.

Suspended Solids. Inorganic or organic matter, such as clay, minerals, decay products and living organisms, that remains in suspension in water. In surface waters it is usually associated with erosion or runoff after rainfall events.

Temporal Variability. Change in some property over time at a specific point in three-dimensional space (*e.g.* the natural change in the chlorophyll-a concentration at the surface of an impoundment near the dam wall).

Total Phosphorus. The sum of phosphorus occurring in particulate matter and soluble (dissolved) orthophosphate.

Trophic Status. The degree of nutrient enrichment and of the associated eutrophication problems of an aquatic ecosystem.

Turbidity. A measure of the light-scattering ability of water. It indicates the concentration of suspended solids in the water.

Water Board. An organ of state established or regarded as having been established in terms of the Water Services Act (No. 108 of 1997) with the primary function of bulk water supply.

Watercourse. A river or spring; a natural channel in which water flows regularly or intermittently; a wetland, lake or dam into which, or from which, water flows.

Water Management Area. An area established as a management unit in the national water resource strategy within which a catchment management agency will conduct the protection, use, development, conservation, management and control of water resources.

Water Management Institution. A catchment management agency, a water user association, a body responsible for international water management or any person who fulfils the functions of a water management institution in terms of the Water Act No. 36 of 1998.

Water Resource. Includes a watercourse, surface water, estuary or aquifer.

Water Services Institution. A water services authority, a water services provider, a water board or a water services committee.

Water User Association. A statutory body of cooperative associations of individual water users who wish to undertake water-related activities for their mutual benefit. The broad role is to enable people within a community to pool their resources to more effectively carry out water-related activities.

Wetland. Land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil.

Zooplankton. See ***Plankton***.

1. INTRODUCTION

This chapter should be read by anyone wanting a brief background to eutrophication monitoring and management in South Africa or an overview of this manual.

CHAPTER CONTENTS

1.1 PURPOSE OF THIS MANUAL

This manual is the primary deliverable of a project funded by the Water Research Commission. It is accompanied by a research report (Murray *et al.*, 2002) that summarises the process of development of this manual and many of the decisions taken in respect of its scope and content.

See National Water Act No 36 of 1998 Chapter 14 Section 143.

In respect of national information systems on water resources, the Minister may make regulations prescribing guidelines for monitoring and on the provision of monitoring data. This manual recommends guidelines, procedures and methods for eutrophication monitoring as well as how and when such data should be reported.

Accordingly, this manual is aimed at a variety of people and organisations. It is initially aimed primarily at DWAF officials who will have the primary responsibility to implement national water-related monitoring programmes. However, it is also aimed at Catchment Management Agencies (CMAs) and water management institutions who will also have monitoring responsibilities. Parts of the manual will also be used by local stakeholders (who will be involved in local monitoring programmes) to provide overall perspective as well as recommendations on procedures that should be followed for the local programme to be a success.

The general purpose of this manual is to describe how the National Eutrophication Monitoring Programme (NEMP) should be implemented at the three spatial scales (namely national, water management area and local).

1.2 BACKGROUND

1.2.1 The need for eutrophication monitoring

Water related policy in South Africa is based on a number of guiding principles. One of the environmental principles is that environmental change should be monitored so that improvements can be encouraged and detrimental impacts minimised. Monitoring eutrophication trends addresses this directly.

See National Water Act No 36 of 1998 Chapter 14.

The National Water Act, No. 36 of 1998 specifically requires that national monitoring systems be established. Eutrophication monitoring is but one aspect of monitoring desirable on a national scale.

Walmsley (2000) has noted that eutrophication is still a major water resource problem in most industrialised countries (*e.g.* USA, Canada, European Union and Australia). Furthermore, these countries have recognised that this is a strategic environmental problem.

Walmsley (2000) noted that, in recent times, some South African impoundments have ranked as some of the most eutrophied in the world. Many South African impoundments still exhibit high nutrient enrichment and eutrophication-related problems [van Ginkel, *et al.*, 2000]. However, the majority of impoundments in South Africa do not have routine eutrophication monitoring programmes.

Eutrophication is of major concern because it can have numerous negative impacts. These include ecological impacts (like deteriorating water quality and loss of biodiversity), aesthetic, recreational and human health impacts. All can have significant economic impacts. As one example, in 1986 Rand Water Board anticipated an increase of about 4% in the consumer cost price (or R7.5×10^6/year) as a direct consequence of increased eutrophication in their raw water sources [Viljoen and van der Merwe, 1986].

Walmsley (2000) has specifically suggested that a national eutrophication monitoring programme include the following.

1. Measure and monitor the inputs of nutrients from anthropogenic and natural sources;
2. Measure and assess the impacts of these inputs (both separately and cumulatively) on receiving waters that are used by society;
3. Measure and assess the performance of remediation/rehabilitation measures;
4. Report regularly (*e.g.* every five years) and transparently on the eutrophication status of South African receiving water systems so as to demonstrate positive or negative trends both on a catchment and a national level.

This manual describes a programme that addresses these issues.

1.2.2 Eutrophication management strategies

Water quality monitoring in general obtains quantitative information on the physical, chemical and biological characteristics of water. The type of information sought depends heavily on the objectives of those responsible for managing the water resources [Sanders *et al*., 1987].

See National Environmental Management Act No 107 of 1998.

Unfortunately, no formal national or Water Management Area eutrophication management strategies exist in South Africa at this time. The National Environmental Management Act No. 107 of 1998 is firmly based on the principle of sustainable development. Furthermore, Walmsley (2000) has emphasised that eutrophication is an environmental problem that should be incorporated into the implementation of this Act. Ideally eutrophication management strategies would have well defined objectives that would in turn sharply focus the monitoring necessary to support associated decisions. In the absence of such specific management objectives, this manual needs to make certain assumptions about the most appropriate management strategies and objectives.

Accordingly, this manual provides a degree of overlap between monitoring (which is the primary focus) and management that at least serves to point the manager in the right general direction. It does not attempt to be comprehensive in respect of appropriate management strategies.

The management strategies being assumed are based on a few basic principles, more detail on which can be found in appropriate sections of this manual. In essence, they include the following.

- They must be consistent with sustainable development that underpins the National Environmental Management Act and necessarily support the National Water Act. This includes the setting of Resource Quality Objectives (RQOs) which are management goals reflecting a future desired state as defined by a water resource class.
- An Adaptive Resource Management (ARM) approach is assumed appropriate. This approach specifically allows for changes in management procedures as new information becomes available.

Management initiatives in the past have been somewhat *ad hoc*. They have tended to be event-based or focus on particular impoundments or problematic species (like water hyacinth, *Eichhornia crassipes*). Every effort should be made in future to rectify the current situation of lack of formal eutrophication management strategies. One way forward is to ensure that they are integrally developed as a part of the catchment management strategies associated with new Catchment Management Agencies. A useful step in the right direction is the availability of two DWAF reports which focus on the water quality management component of catchment management strategies [DWAF, 2000a; DWAF 2001a]. These two documents are extremely important because they address a wide range of management questions. These questions are reproduced here for convenience.

Management questions addressed by the Guide to Conduct Water Quality Assessment Studies:

1. What is the study area's status in water-related terms and how did it get to this point?
2. What are the water-related stakeholders and institutions in the study area and what are their respective jurisdictions, relationships, linkages and roles?
3. What are the study area's water quality issues, problems, concerns and opportunities?
4. Where might the water quality status of the study area be heading in the future?
5. What are the appropriate (priority) water quality management options?
6. Has water quality management achieved its objectives?

It is clear from this list of questions that monitoring, on the one hand, requires answers to some of the questions, and, on the other hand, helps to answer others. Consulting these documents is essential [DWAF, 2000a; DWAF 2001a].

1.2.3 Past and existing eutrophication monitoring

Much *ad hoc* eutrophication monitoring has been done over the past few decades in South Africa. Extensive research projects were undertaken between 1972 and 1985 that were supported by the Water Research Commission (WRC) that resulted in much monitoring data [*e.g.* Toerien *et al.*, 1975].

One more recent project, resulting in a report assessing the Trophic Status Project, has provided very useful recent information on 49 of the 250 South African impoundments [van Ginkel, *et al.*, 2000]. This project provides a critically important basis for the design of a national monitoring programme. Some impoundments have extensive eutrophication data measured from as early as 1986. The principal variables measured included chlorophyll *a*, total phosphorus, the percentage of cyanobacteria and Secchi disc depth.

The larger bulk water suppliers, such as Umgeni and Rand Water, and some metropolitan councils (like Cape Metropolitan Council) and other organisations have been monitoring eutrophication-related variables for many years for their own purposes. Their data and experience are invaluable for the design and implementation of the NEMP at local, regional and national level.

1.3 THE NEMP SPATIAL MONITORING SCALES

Three distinct spatial tiers have been chosen as potentially associated with different management objectives. These are 'national', 'regional' (Water Management Area) and 'local area' perspectives. Water Management Areas refer to the 19 formal areas designated by DWAF covering the whole of South Africa. 'Local area' refers here to any smaller unit of area. This may be a catchment of a single impoundment or river reach and its immediate vicinity. The following figure illustrates the three levels.

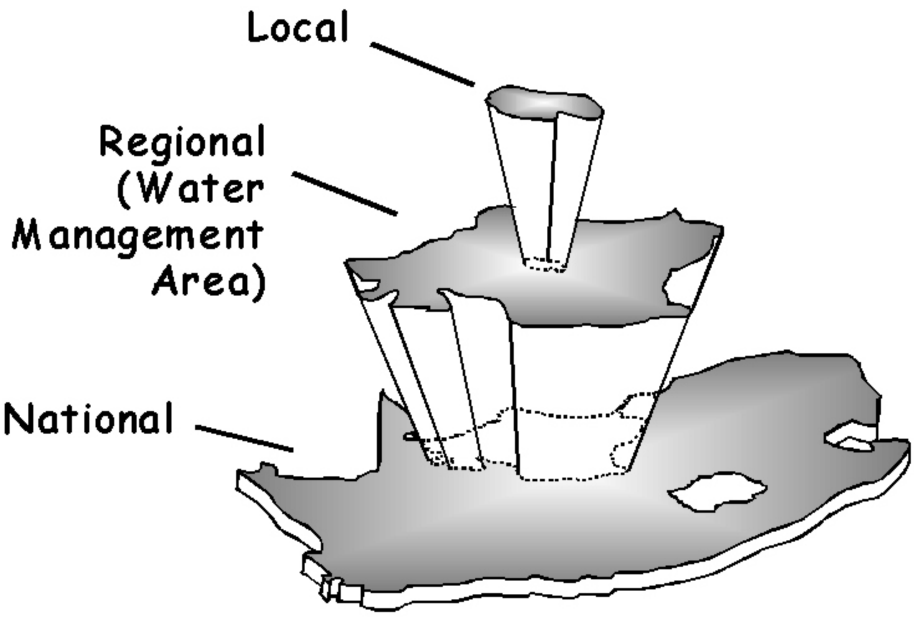


Figure 1.1. Schematic illustration of the three spatial monitoring scales assumed for the National Eutrophication Monitoring Programme.

1.4 THE STRUCTURE OF THIS MANUAL

Chapter 2 describes
the causes and impacts of eutrophication

Chapter two describes the main factors that cause eutrophication. It also focusses on some of the main negative impacts of the various ways in which eutrophication manifests itself.

Chapter 3 describes a national implementation process

Chapter three describes the national objectives and the overall national implementation process of the NEMP. In particular it deals with the tasks of the National Coordinator.

Chapter 4 describes a regional implementation process

Chapter four describes the process for implementing the programme in a Water Management Area. It focusses on the tasks of the Regional Monitoring Coordinator.

Chapter 5 describes local implementation

Chapter five deals with the process of implementing the national programme in a local area in a way that addresses both local, regional and national aims. It addresses creating local capacity and adapting the generic monitoring frameworks through to the point of registering the local monitoring programme formally with DWAF.

Chapter 6 describes monitoring frameworks

Chapter six describes frameworks for local monitoring programmes that address a variety of specific local objectives.

Chapter 7 defines monitoring procedures

Chapter seven defines such procedures as sampling and analysis that will ensure a satisfactory standardisation of methods nationwide.

Chapter 8 defines individual roles and responsibilities

Chapter eight defines the individual roles from sampler to the national policy maker and summarises the data and information flow.

Chapter 9 deals with finances and other business issues

Chapter nine deals with various business-related aspects of national monitoring. These include funding sources, costing of national, regional and local monitoring programmes and sustaining commitment.

Chapter 14 of the Water Act
(Monitoring: Assessment & Information)
is reproduced as an appendix

2. EUTROPHICATION

This chapter should be read by anyone wanting a brief summary of the causes, the impacts and the management of eutrophication.

CHAPTER CONTENTS

2.1 INTRODUCTION

The word 'eutrophic' comes from the Greek word *eutrophos* meaning well-fed. A variety of definitions of 'eutrophication' exist in the literature, some differing fundamentally from others. One difference is in respect of whether eutrophication is only the process of nutrient enrichment or whether it should include the problems associated with such enrichment. In South Africa, the latter is the generally accepted view. Rast and Thornton (1996) state that "eutrophication is the natural ageing process of lakes". Others suggest that eutrophication is the *enhancement* of the natural process of biological production caused by nutrient enrichment [Chorus and Bartram, 1999].

A widely quoted definition in South Africa is that "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 are found to be undesirable and interfere with water uses [OECD, 1982]".

This definition is somewhat clumsy. It is also not necessary that a complex definition is adopted for the present purposes. In essence, eutrophication is nutrient enrichment that causes problems. Therefore, the following simplified definition is adopted.

Eutrophication is the process of excessive nutrient enrichment of waters that typically results in problems associated with macrophyte, algal or cyanobacterial growth.

While an enormous amount of literature has been published on this topic, a detailed treatment is outside the scope of this report. A recent local review [Walmsley, 2000] provides important perspectives on eutrophication of surface waters with particular emphasis on policy and research needs in South Africa. It contains a very useful list of references which can be consulted for more detailed information.

The causes and effects of eutrophication are complex. This chapter only summarises briefly the current state of knowledge. Internationally, much research work is in progress that aims at furthering our knowledge of the intricate interrelationships involved in eutrophication of water resources. A paper by Rast and Thornton (1996) can be consulted for more information on research trends.

2.2 CAUSES

2.2.1 Introduction

In *natural* lakes a distinction is sometimes made between 'natural' and 'cultural' (anthropogenic) eutrophication processes (*e.g.* Rast and Thornton (1996)). Natural eutrophication depends only on the local geology and natural features of the catchment. Cultural eutrophication is associated with human activities which accelerate the eutrophication process beyond the rate associated with the natural process (*e.g.* by increasing nutrient loads into aquatic ecosystems). In South Africa where impoundments are man-made, the conceptual difference between 'natural' and 'cultural' seems less appropriate.

Increased nutrient enrichment can arise from both point and non-point sources external to the impoundment as well as internal sources like the impoundment's own sediments (that can release phosphate).

The adjacent figure illustrates some of the factors that drive the eutrophication process in an impoundment.

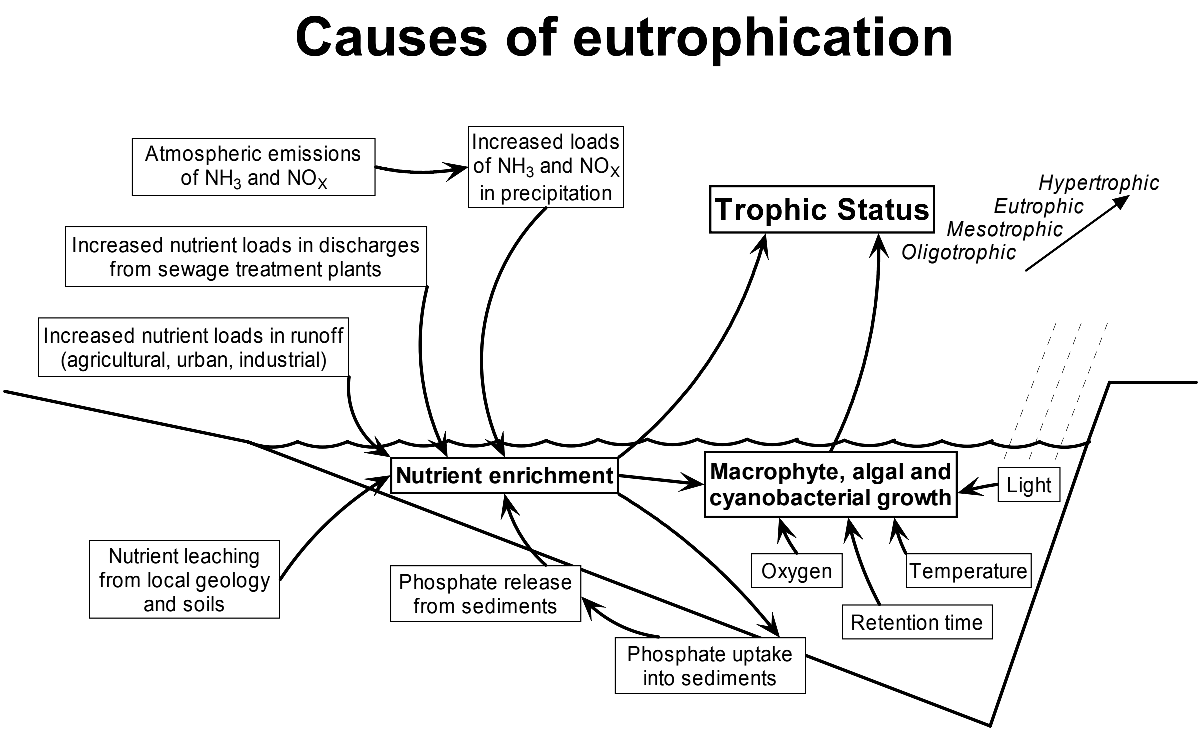


Figure 2.1. Simplified schematic illustration of the most important factors driving the eutrophication process.

2.2.2 Trophic status

Eutrophication is a process and it is useful to be able to characterise the stage at which this process is at any given time in a particular water body. The 'trophic status' of the water body is used as a description of the water body for this purpose. The following terms are used [Walmsley, 2000].

Oligotrophic - low in nutrients and not productive in terms of aquatic animal and plant life.

Mesotrophic - intermediate levels of nutrients, fairly productive in terms of aquatic animal and plant life and showing emerging signs of water quality problems.

Eutrophic - rich in nutrients, very productive in terms of aquatic animal and plant life and showing increasing signs of water quality problems.

Hypertrophic - very high nutrient concentrations where plant growth is determined by physical factors. Water quality problems are serious and almost continuous.

It is convenient to associate the trophic status in impoundments with total phosphorus and chlorophyll *a* measurements. The following relationships between trophic status and these variables are used. These are essentially those of Van Ginkel *et al.* (2000), which were based on the work of Walmsley and Butty (1980) and Walmsley (1984). These have been shown to be applicable to South African impoundments.

Table 2.1. Relationships between trophic status and monitoring variables.

		Trophic Status			
Variable	**Unit**	**Oligotrophic**	**Mesotrophic**	**Eutrophic**	**Hypertrophic**
Mean annual chlorophyll *a*	$\mu g/\ell$	$0<x\leq 10$	$10<x\leq 20$	$20<x\leq 30$	>30
% of time chloropyll *a* > 30 $\mu g/\ell$	%	0	$0<x\leq 8$	$8<x\leq 50$	>50
Mean annual Total Phosphorus	mg/ℓ	$x\leq 0.015$	$0.015<x\leq 0.047$	$0.047<x\leq 0.130$	>0.130

Trophic status is therefore strictly related to one of the nutrients (namely phosphorus) and concentrations of planktonic algae and cyanobacteria (as chlorophyll *a*). (Note that it is not necessarily directly related to concentrations of macrophytes or algae attached to rocks and other surfaces.) It is also possible to have a relatively high nutrient concentration and yet low plant growth (*i.e.* low chlorophyll *a*). For example, this can occur if light availability is reduced because of high levels of suspended solids or if high flushing rates occur.

2.3 IMPACTS

2.3.1 Introduction

Eutrophication is a concern because it has numerous negative impacts. The higher the nutrient loading in an ecosystem the greater the potential ecological impacts. Increased productivity in an aquatic system can sometimes be beneficial. Fish and other desirable species may grow faster, providing a potential food source for humans and other animals (though this is not a common situation in South Africa). However, detrimental ecological impacts can in turn have other adverse impacts which vary from aesthetic and recreational to human health and economic impacts. This is summarised in the following figure.

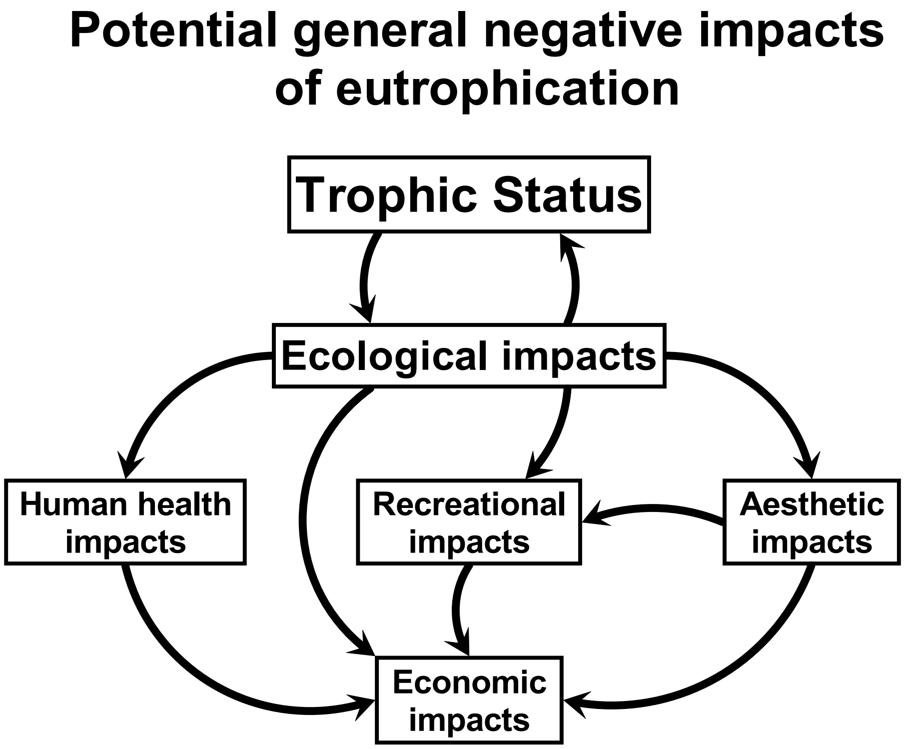


Figure 2.2. Summary of potential general negative impacts of a high trophic status.

The more detailed impacts of eutrophication are complex and interrelated. The excessive growth of aquatic plants and cyanobacteria has a multitude of impacts on an ecosystem. The specific impacts depend on what plants are stimulated to grow.

Potential negative impacts of eutrophication

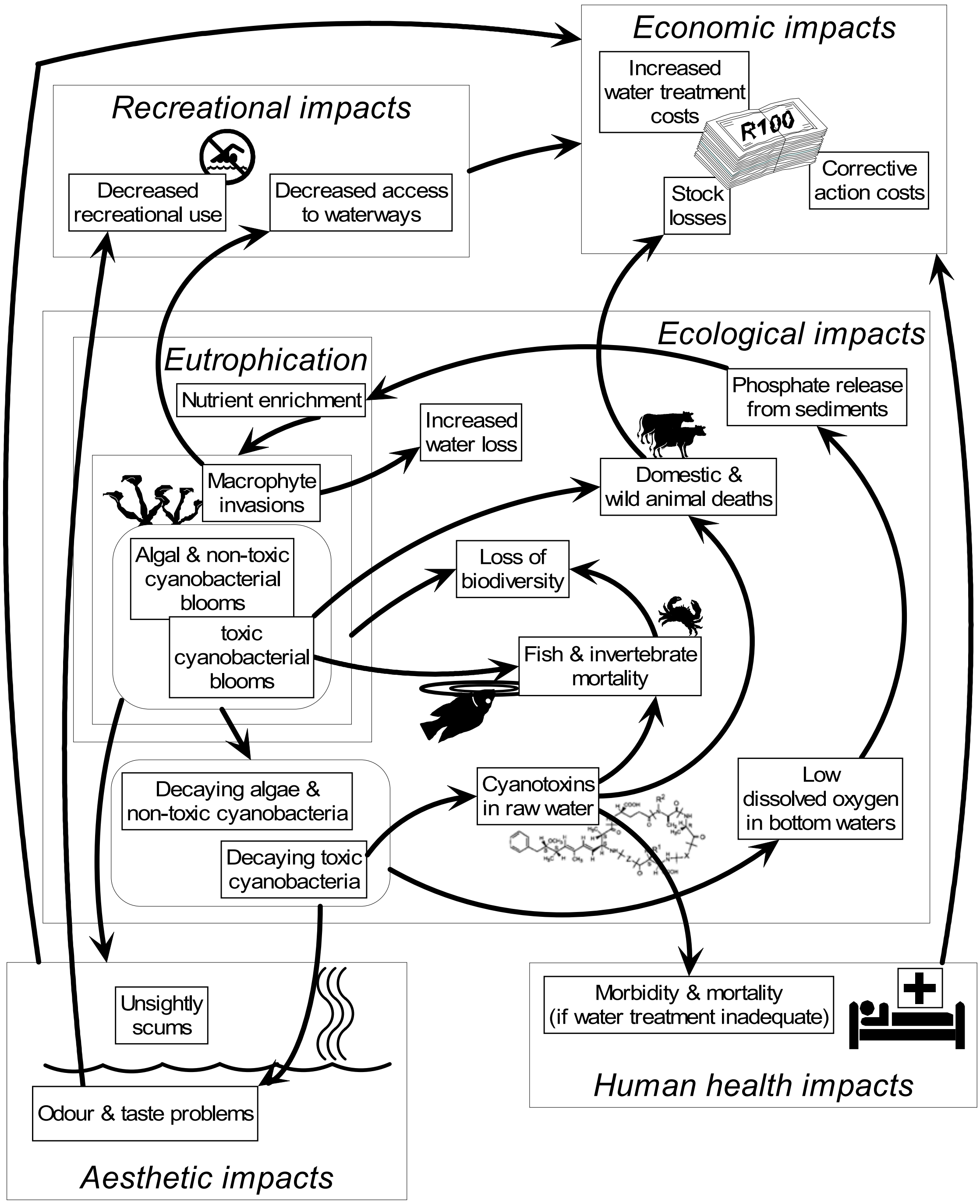


Figure 2.3. Schematic illustration of some specific impacts of eutrophication.

2.3.2 Ecological impacts

Macrophyte invasions and algal and cyanobacterial (blue-green) blooms are themselves direct impacts on an ecosystem. However, their presence causes a number of other ecological impacts.

Of critical concern is the impact of eutrophication on biodiversity. Macrophyte invasions impede or prevent the growth of other aquatic plants. Similarly, algal and cyanobacterial blooms consist of species that have out-competed other species for the available nutrients and light.

Their impact on animal biodiversity is also of concern. By generally lowering the ecological integrity of an ecosystem, only the more tolerant animal species can survive.

Cyanobacteria (also known as blue-green algae) and algae require water, carbon dioxide, inorganic substances and light for their life processes [Chorus and Bartram, 1999]. Cyanobacteria are found widely in nature and flourish in water that is salty, brackish or fresh, in cold and hot springs and in environments in which no other algae can exist. The basic forms and structure include unicellular, colonial and multicellular filamentous forms. The growth rate of cyanobacteria is usually much lower than that of many algal species. The following table shows comparative growth rates for some organisms (in number of days to double the biomass).

Table 2.2. Comparative growth rates for some organisms at 20°C and light saturation [Chorus and Bartram, 1999].

Organism	Growth rate range (days per doubling)
Most common planktonic cyanobacteria	0.7 - 3.3
Diatoms	0.5 - 1.3
Single-celled green algae	0.4 - 0.8

Cyanobacteria can maintain a relatively higher growth rate compared to other phytoplankton organisms when light intensities are low. They will therefore have a competitive advantage in waters that are turbid due to dense growths of other phytoplankton. Maximum growth rates are attained by most cyanobacteria at temperatures above 25°C. These optimum temperatures are higher than for green algae and diatoms [Chorus and Bartram, 1999].

Cyanobacteria can form floating scums (like *Microcystis*), be distributed homogeneously throughout the epilimnion (like *Oscillatoria*) or grow on submerged surfaces. Cyanobacteria are particularly problematic because when their cells are ruptured (*e.g.* by decay or by algicides) they release toxic substances (cyanotoxins) into the water, though passive release can also occur. These cyanotoxins fall into three broad groups of chemical structure: cyclic peptides, alkaloids and lipopolysaccharides. Globally, the most commonly found cyanotoxins in blooms from fresh and brackish waters are the cyclic peptides of the microcystin and nodularin family [Chorus and Bartram, 1999].

Cyanotoxins are recognised to have caused the deaths of wild animals, farm livestock, pets, fish and birds in many countries [Holdsworth, 1991]. The primary target organ of most cyanotoxins in mammals is the liver (*i.e.* they are hepatotoxic). Some cyanotoxins are neurotoxic (target the nervous system) and others dermatotoxic (target the skin). Ecological impacts include various water quality impacts like increased cyanotoxin levels and lowering of oxygen levels (due to decay of algae and cyanobacteria). Decreased oxygen levels can have a number of other secondary water quality impacts. Anaerobic conditions allow reduced chemical species (like ammonia and sulfide) to exist. These chemicals can be particularly toxic to animals and plants.

2.3.3 Aesthetic impacts

Algal and cyanobacterial blooms, and particularly surface scums that might form, are unsightly and can have unpleasant odours. This is often a problem in urban impoundments where people live close to the affected water body.

If the water is being used for water treatment purposes, various taste and odour problems can occur. These lower the perceived quality of the treated water, although do not cause human health problems.

2.3.4 Human health impacts

An infestation of water hyacinth (*Eichhornia crassipes*) can be a health hazard. It can provide an ideal breeding habitat for mosquito larvae and it can protect the snail vector of bilharzia [Scott *et al.*, 1979].

Of all the cyanotoxins currently known, the cyclic peptides represent the greatest concern to human health, although this may be because so little is known about the other cyanotoxins [Chorus and Bartram, 1999]. The concern exists primarily because of the potential risk of long term exposure to comparatively low concentrations of the toxins in drinking water supplies. Acute exposure to high doses may cause death from liver haemorrhage or liver failure. Other short term effects on humans include gastrointestinal and hepatic illnesses. A number of adverse consequences have been documented for swimmers exposed to cyanobacterial blooms. Chronic exposure to low doses may promote the growth of liver and other tumours. Nevertheless, many cyanobacterial blooms are apparently not hazardous to animals [Carmichael, 1992].

It is also possible that people exposed to odours from waterways contaminated with decaying algae of cyanobacteria may suffer chronic ill-health effects.

2.3.5 Recreational impacts

The existence of large areas of macrophytes can inhibit or prevent access to waterways. This decreases the fitness for use of the water for water sports such as skiing, yachting and fishing. The presence of unsightly and smelling scums also makes any recreational use of the water body unpleasant.

2.3.6 Economic impacts

Nearly all of the above mentioned impacts have direct or indirect economic impacts. Algal or cyanobacterial scums increase the costs of water treatment in order to avoid taste, odour and cyanotoxin problems in the treated water. Excessive blooms can clog filters and increase maintenance costs.

Human and domestic and wild animal health impacts due to cyanotoxins in water have obvious direct economic impacts.

Once significant eutrophication has occurred, the costs of corrective action can be enormous. Macrophytes may need to be sprayed or brought under control by biological or other costly treatment processes.

2.4 MANAGEMENT

The basis of eutrophication management is often the 'limiting nutrient concept' [Walmsley, 2000]. The rate and extent of aquatic plant growth is dependent on the concentration and ratios of nutrients present in the water. Plant growth is generally limited by the concentration of that nutrient that is present in the least quantity relative to the growth needs of the plant. Minimisation of eutrophication-related impacts therefore tends to be focussed on efforts to reduce nutrient (particularly phosphorus) inputs. This approach therefore deals directly with the primary cause of eutrophication (namely, nutrient enrichment).

Typically, limiting nutrients entering an impoundment exhibiting a high degree of eutrophication will first focus on point sources. These are easier to quantify, simpler to manage and often contribute the highest nutrient load. Following this, non-point sources are managed and then internal ("in-lake") management options can be implemented.

Readers are referred to Walmsley (2000) for a recent review of local and international eutrophication management perspectives. He notes that successful eutrophication management depends on the acceptance of certain perspectives. These include the following.

1. Cultural eutrophication is reversible.
2. There is no quick fix. Long term approaches are required to solve the problem.

3. Collaboration is required between government, business and communities. However, government must play the lead facilitation role.
4. The problem cannot be solved by a single technical intervention. It requires a suite of social, economic and technical actions.
5. Transparent research and monitoring activities are prerequisites to the decision-making that is required.

The excellent work by Chorus and Bartram (1999) on toxic cyanobacteria in water contains much detailed management information. Although primarily focussed on the cyanobacteria, many of the principles are likely to be appropriate in other eutrophication contexts. A report on management of urban impoundments in South Africa is also available which provides an overview of current practice (though not only focussed on eutrophication) which has applicability beyond just urban impoundments [Wiechers *et al.*, 1996]. Publications on the biological control of some aquatic macrophytes in South Africa are also available [Hill and Cilliers, 1999; Cilliers, 1999].

Other management approaches such as harvesting of macrophytes (like the cattail, *Typha capensis*) and biological control (of, for example, water hyacinth, *Eichhornia crassipes*) are, by their very nature, focussed on the symptoms of the eutrophication problem. However, macrophyte harvesting does little to remove nutrients (that would move into the aerial and rhizome biomass).

A drinking water supply safe from cyanotoxins should either be free of cyanotoxins, or have treatment in place that will remove cyanobacterial cells (without rupturing them) and released cyanotoxins [Chorus and Bartram, 1999]. From a recreational point of view, similar measures of resource protection apply as for drinking water. However, a series of guidelines have been proposed associated with incremental severity and probability of adverse effects [Chorus and Bartram, 1999].

3. NATIONAL IMPLEMENTATION

This chapter should be used primarily by the National Coordinator for overall guidance on the implementation process of the NMMP at a national level.

CHAPTER CONTENTS

3.1 NATIONAL OBJECTIVES

Although much *ad hoc* eutrophication monitoring exists in South Africa, there is not a coordinated national programme at this time. The National Eutrophication Monitoring Programme (NEMP) addresses this issue. It is primarily an initiative (and the responsibility) of the Department of Water Affairs and Forestry (DWAF). It is a 'status and trend' monitoring programme, the design of which is described in this manual.

The NEMP will have the following primary objectives.

National Eutrophication Monitoring Programme
DWAF National Objectives

To measure, assess and report regularly on
(1) the current trophic status,
(2) the nature of current eutrophication problems,
(3) the potential for future changes in trophic status
in South African impoundments and rivers
in a manner that will
support strategic decisions in respect of their national management,
be mindful of financial and capacity constraints, yet,
be soundly scientific.
(What are the eutrophication problems in South Africa,
how bad are they and what are the likely future problems?)

Note that the objectives as stated are *monitoring objectives*, not management objectives. However, the latter are, to some extent, implied in these monitoring objectives by the focus on "trophic status and nature of eutrophication problems". That is, it is being assumed that national eutrophication management objectives (however they might be explicitly expressed) will require knowledge of the extent and nature of eutrophication.

See National Water Act No 36 of 1998 Chapter 14 Section 137.

The most generic expression of the highest level national management needs are provided by the National Water Act No. 36 of 1998. At a national level, organisations such as DWAF or DEAT need to have a national picture of the degree to which eutrophication is a problem and how this is changing over time. (These are somewhat more specific management objectives than implied above.) It is the creation of this national picture that ultimately makes this a **national** programme.

More specifically, eutrophication monitoring addresses the 'information management' function of Water Resource Management. This is described as "managing the monitoring, collection, storage and assessment of water resources, social, economic and institutional data and information required, as a support to the other WRM functions" [DWAF 2001b]. These other functions include policy and strategy, water use regulation, physical implementation, institutional support and auditing.

Typically, such water resource management would form an integral part of the catchment management strategy that should exist in each Water Management Area (associated with the Catchment Management Agency).

3.2 IMPLEMENTATION ISSUES

3.2.1 Introduction

A process with well-defined actions for national implementation is defined later in this chapter (section National Implementation Process). However, there are many generic issues that have to be borne in mind during this process. This section describes these issues. They should be especially carefully considered and implemented by the National Coordinator of the NEMP.

3.2.2 Responsibilities

As noted above, the NEMP (specifically, meeting the above-stated national objectives) is the responsibility of the Department of Water Affairs (DWAF). However, this manual provides considerable emphasis on regional and local monitoring programmes as well. These latter programmes should be regarded as distinct programmes in their own right with their own objectives (see chapters on Regional Implementation and Local Implementation). Importantly, these regional and local programmes are *not* automatically the primary responsibility of DWAF (although data collected by them will be the data that meet the national objectives). However, DWAF may choose to make them its responsibility if, for example, a particular local programme is required to meet the national objectives for which local non-DWAF stakeholders cannot be found. In such a case, DWAF can take full responsibility for the local programme.

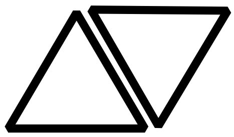
The detailed emphasis given to regional and local monitoring programme designs in this manual is done to facilitate and simplify the establishment of such programmes *so that the national objectives are met*. Specifically, these designs can be presented to regional and local stakeholders as recommended points of departure upon which actual designs can be negotiated. Consultation and negotiation can then proceed and the National Coordinator must ensure that the minimum requirements for meeting national objectives are in place. A mutually beneficial decision should then be made on who takes what responsibilities. This should form the basis of a formal contract between DWAF and the local parties.

The purpose of this approach is to strive for a win-win situation whenever possible in which regional and local programmes not only address their respective objectives but those of the national programme as well. Ideally, local programmes should be designed in such a way that local, regional and national objectives are met simultaneously.

3.2.3 Water Resource Management restructuring

In early 2000, DWAF commissioned a Strategic Restructuring and Transformation Project, focussing on the water resources management (WRM) function and water services in the regional offices [DWAF 2001b]. This is a lengthy process likely to take many years. The national coordinator of the NEMP will need to be aware of this process and ensure that implementation decisions are appropriately aligned with current thinking and, in particular, with envisaged future thinking. If this is not done, sustainability of the NEMP could be seriously compromised.

3.2.4 Bottom-up then top-down management



Similar to the River Health Programme, the successful implementation of the NEMP will involve a careful combination of bottom-up and top-down approaches [Murray, 1999]. The top-down approach will have its basis in the current legislation and the creation of an infrastructure to implement and check compliance. The bottom-up approach will be based on identifying those local and regional concerned parties who will themselves benefit from involvement in the NEMP. At any particular time, site-specific circumstances will dictate which approach will be the most applicable and the outcome of negotiations between DWAF and local and regional stakeholders.

It is very likely that prior to the establishment of Catchment Management Agencies that a bottom-up approach will be more applicable. Thereafter, the approach may gradually become more top-down (but probably never exclusively so).

In essence, the NEMP is encouraged initially to ‘go local’ with the specific aim of encouraging local players to find a ‘win-win’ solution in which they see a well-defined return on their investment. They need to be provided with the tools for local implementation in such a way that a contribution to the regional and national objectives is ensured.

3.2.5 Anticipating the problems

It is important that the implementation of the NEMP learn from the experiences of other national monitoring programmes. The River Health Programme (RHP) has encountered a number of problems in its endeavours at implementation on a national basis [Murray, 1999]. Although fundamentally more complex than the NEMP, it is appropriate to take note of those problems and ensure that the implementation strategy of the NEMP is able to avoid or minimise them as much as possible.

The most common problems were the following.

At the highest level, lack of accountability and resource constraints were the two main driving forces of ineffective implementation.

Lack of accountability involved (1) a lack of clarity on responsibility for implementation, (2) the non-statutory status of the RHP and (3) the lack of support from superiors (especially in government departments).

The lack of accountability tends to be associated with an inability to apply (or inappropriateness of) a top-down approach to implementation (see below for more detail). With the advent of Catchment Management Agencies funded through water charges, this approach is likely to become more appropriate and therefore less problematic.

Resource constraints entailed (1) the high cost of consultants, (2) the lack of trained personnel and (3) time constraints.

The NEMP can deal with the resource-related problems in the following ways. First, a tool is available that allows financial planning for local, regional and national monitoring programmes. So the costs (human resource, capital and operating) can be quantified up front. Monitoring and analysis methods are kept as simple and as cheap as possible (without sacrificing scientific integrity). This means that the required expertise, and hence training requirements, are minimised. Simple sampling and analytical methods also minimise the time requirements.

3.2.6 National coordination

See National Water Act No 36 of 1998 Chapter 14 Section 138.

The Department of Water Affairs and Forestry (DWAF) has a mandate under the National Water Act to monitor water resources. There are also general statutory requirements in respect of coordinating the monitoring of water resources in South Africa. DWAF has the primary responsibility for the implementation of national eutrophication monitoring.

A person must be formally assigned the role of **National Coordinator**. (For a full description of this role and others see the chapter Roles and Responsibilities.)

The primary role of the National Coordinator is to facilitate the nationwide implementation of the NEMP so that the national objectives are achieved. The National Coordinator will need to be familiar with all aspects of eutrophication monitoring and should be able to provide technical and managerial advice to the various role players. The National Coordinator must also ensure effective and efficient transfer of knowledge and experience gained by those already involved in the programme.

The National Coordinator should be the driving force behind initial and ongoing implementation on a national basis.

A critical task in the initial stages will be to ensure that Catchment Management Agencies include a eutrophication management strategy in their catchment management strategies.

It is the intention that the National Coordinator plays a hands-on management role. A significant commitment is required from the National Coordinator (and that person's superiors). The National Coordinator should be a 'doer' not a 'delegator'. In this way, the work of the National Coordinator will achieve more depth. National *coordination* is likely to be more consistent and efficient (since the execution of tasks will be less fragmented, because they are being done primarily by a single person).

One aspect of national coordination will be the approval of local monitoring programmes submitted by the Regional Monitoring Coordinator (see the chapter Roles and Responsibilities). This is the first step in the overall process of quality control. The primary purpose of this approval is to ensure that the design of the local programme fulfils the requirements of providing data that not only addresses the identified local objectives but also the regional and national objectives. (For example, appropriate variables must be measured at an appropriate frequency, and so on.)

3.2.7 Demonstrating early successes

The National Aquatic Ecosystem Biomonitoring Programme (NAEBP) (or River Health Programme) is implementing a so-called 'Demonstration-for-Resource Allocation Spiral' model. A similar approach should be adopted for the National Eutrophication Monitoring Programme.

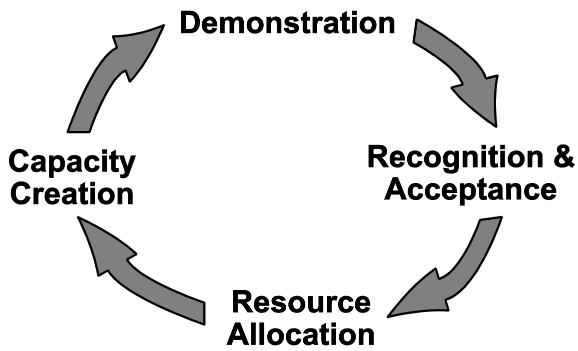


Figure 3.3. The 'Demonstration-for-Resource Allocation Spiral' model of the River Health Programme [Roux, 1997].

In the case of the NAEBP, small-scale demonstration of the role of biomonitoring in water resource assessment and management led to a recognition of its usefulness. This recognition, and the acceptance of a need for the technology, resulted in the further allocation of resources (financial and human). Basically, this approach assumes that demonstrating good results leads to increased support.

Initially, the National Coordinator must choose one Water Management Area (WMA) which can be used to demonstrate the usefulness of eutrophication monitoring to other WMAs. However, a failed attempt could have disastrous consequences and delay ultimate implementation significantly. Therefore, the NEMP must 'get it right first time'. Accordingly, these initial areas must be carefully chosen and should satisfy at least the following criteria:

- ✓ **Existing capacity.** There must be as much existing capacity in the area as possible. This means there must already exist players who have the capacity to adopt the roles required in the area. It is also assumed that a regional DWAF or CMA person will have the necessary capacity.
- ✓ **Local Willingness.** The local and regional players should reap well-defined benefits from involvement in the local programme. That is, there should be an inherent willingness to get involved.
- ✓ **Real Issues.** The area should be experiencing significant eutrophication-related problems. This can be based on the prioritisation process outlined below. Alternatively, the area should have a high risk of problems, possibly based on previous problems in the area.
- ✓ **Suitability for Demonstration.** It should be remembered that one purpose of this exercise is to demonstrate success. Factors other than those identified here which may enhance or impede the chances of success will need to be identified and carefully considered.

'Success' in this context will be achieved if a regional monitoring programme (1) is collecting data according to the prescribed framework(s), (2) provides regular reports to the appropriate interested parties and (3) those parties are willing to acknowledge the usefulness of the programme.

The above criteria essentially make initial implementation as easy as possible by minimising many of the most obvious difficulties. Initial successful implementation of eutrophication monitoring will help in a number of ways. First, a tangible success minimises the need to rely on theoretical marketing of eutrophication monitoring. The marketing is therefore much more convincing and hence likely to result in a commitment of resources. Secondly, technical and managerial problems (that will inevitably exist, notwithstanding the above criteria) will be identified and be overcome. This will increase the chances of future successes in areas in which implementation is inherently more difficult.

3.2.8 Prioritisation

As noted above, the initial choice of WMAs (and local impoundments within WMAs) should depend on (among other factors) the severity of eutrophication-related problems actually occurring. Accordingly, a process of prioritisation of impoundments has been undertaken that provides some guidance on those impoundments in which the most serious problems have been occurring.

Specifically, the objectives of the prioritisation process at a national level were as follows:

National prioritisation objectives: To determine which impoundments (and hence WMAs) are experiencing the worst eutrophication-related problems. This is primarily to facilitate the initial choice of WMAs and individual impoundments during the proposed phased implementation of the NEMP so that the cost-effectiveness of the monitoring resources is maximised.

Importantly, the prioritisation process that was developed assumed that it was not necessary that an accurate final prioritised list of impoundments (and hence WMAs) be compiled. This is for a number of reasons. On the day that choices have actually to be made, a number of other factors of (currently unpredictable) importance will play a role. These factors include those noted above (existing capacity and so on) as well as various other practical issues. Furthermore, it is only necessary that the worst cases be known, not that all 250 impoundments in South Africa are correctly ordered.

The prioritisation process was based on a specific set of attributes chosen because of their likelihood of determining or being associated with severe eutrophication problems. Attributes were chosen that were based on land use in the catchment of each impoundment (urban, agricultural, industrial and natural) and inorganic nutrient concentrations (PO_4-P and NO_3+NO_3-N) in the impoundments. Each attribute was given a relative weight.

The resulting prioritised list of some 118 impoundments compared satisfactorily with the results of an independent (and more thorough) process performed on 43 impoundments that have extensive data over a long period of time [van Ginkel *et al.*, 2000].

The results of the process can be found in the research report associated with the development of this manual [du Preez *et al.*, 2002]. These results are likely to be sufficiently accurate for the first few years of NEMP implementation. Subsequently, the prioritisation can be repeated on impoundments not yet included in the NEMP to obtain a more up to date list of those worst affected by (or at risk of) severe eutrophication.

3.2.9 Creating awareness

Generic mechanisms (applicable nationwide) must be identified for conveying information on the NEMP to all interested parties.

One such mechanism is a regular (*e.g.* six-monthly) newsletter. This should be produced by (or under the guidance of) the National Coordinator and contain information that deals with the following kinds of issues.

- ❏ Demonstrating the usefulness of the NEMP to encourage recognition and acceptance (*i.e.* applying the 'Demonstration-for-Resource Allocation Spiral' model for implementation).
- ❏ Enabling potentially interested parties to identify whether they can benefit from the programme.
- ❏ Keeping readers up to date with implementation progress (*e.g.* what areas are currently included).
- ❏ Educating readers in eutrophication-related causes and impacts.
- ❏ Describing how one becomes involved in the national programme.

Another mechanism is the development and regular updating of a web site specifically focussed on the NEMP. The same issues as above can be addressed. Indeed, the newsletter itself should be available on the web site.

3.2.10 Creating capacity

Monitoring eutrophication requires special skills. These include sampling techniques, *in situ* visual monitoring techniques and laboratory techniques such as phytoplankton identification and counting. It will be important to ensure that sufficient capacity (of appropriate standard) is created in South Africa to meet the needs of the national programme. There exist, at the time of writing, only a few centres with the necessary expertise, particularly in respect of phytoplankton identification. Some already offer courses that can be used as a basis for future capacity creation.

Collaboration with these existing centres of expertise will be necessary to ensure transfer of the appropriate knowledge. Technicons may also be appropriate organisations that can be used to give certain courses. The development of courses for consultants, nature conservation officers, water control officers (within DWAF) and so on should be considered.

The National Coordinator should oversee the design and implementation of all training courses (thus ensuring standardisation). Sampling, although relatively straightforward, also requires a degree of training. The correct use of such apparatus as the Secchi disk, the 5m hosepipe and the filter apparatus (for chlorophyll *a* analyses) need to be explained carefully, preferably on site. (See Procedure Specifications chapter.)

Phytoplankton identification and counting is best done using an inverted microscope. This is an expensive item. If it is found that the existing laboratories cannot handle the load from the NEMP, then more microscopes may need to be bought. Capacity will also need to be created so that they are correctly used and maintained.

The exact degree to which new capacity needs to be created in South Africa will depend on strategic decisions made by DWAF senior management. In particular, the rate at which the NEMP should be implemented (*e.g.* as represented by the number of new impoundments contributing to the NEMP each year), will be a critical determining factor. This will determine the rate at which new sampling and laboratory capacity needs to be created.

Capacity creation will not only be associated with the procedures noted in this manual. It will also be determined by the results of future research that should be conducted to improve the current monitoring design.

3.2.11 Database management

3.2.11.1 Water quality data

Quantitative water quality data (such as those collected for trophic status) should be stored in the Water Management System (WMS) at DWAF. This system is still under development though is being used. The National Coordinator should ensure that the WMS develops in a way that addresses any specific requirements of the NEMP that may not already be catered for.

The WMS is a comprehensive system well suited to storing, managing, quality control and reporting on water quality data. It’s many inbuilt protocols and other facilities are specifically designed for national and local monitoring programmes. For example, a wide variety of checks are made on all data entered before the data are formally accepted into the database. Full use should be made of WMS. However, certain potential users have noted current inadequacies. Any shortcomings that impede the implementation of the NEMP should be identified by the National Coordinator as soon as possible and efforts put in place to rectify them.

3.2.11.2 Macrophyte and phytoplankton data

A project is currently underway to develop an agricultural information system (AGIS) for South Africa [see http://www.agis.agric.za]. Since excessive plant growth (algal to macrophyte) will be monitored within the National Eutrophication Monitoring Programme, the use of AGIS as the database and reporting protocol within the NEMP is an attractive option. This is currently being investigated. The following summary is taken from the web site.

AGIS is intended to support effective policy formulation and decision making at all levels. GIS (Geographical Information System) technology can facilitate the storage, analysis and interpretation of geo-referenced information, including maps. With its current affordability and availability, this was seen as the only practical option to assist in the current problems being faced in South Africa to address the following.

- National Growth and Development Strategies (NGDS).
- Compliance with international protocols, treaties, conventions, agendas (e.g. Agenda 21, convention on biodiversity, desertification and climate change).
- Global sustainability programmes.
- Promotion of the Growth, Employment and Redistribution (GEAR) framework.

It is envisaged that AGIS will be co-ordinated by a coordinating body appointed by the Minister of Agriculture and Land Affairs and recommended by the National and Provincial Departments of Agriculture and the Agricultural Research Council. Training, capacity building and active information dissemination will be an integral part of its business.

Various databases will be developed. A meta-database will also be developed that will supply information on what data is available, the definition of each data element, whether the data meets specific needs (fitness for use), how to acquire it, and how to extract it for local use.

Ultimately the database will lead to the development and incorporation of models and processes that could be included in decision support systems that will benefit decision makers at all levels of government and those involved in the agricultural sector.

One of the databases to be included in AGIS is SAPIA (Southern African Plant Invaders Atlas). This has been developed at the National Botanical Institute in Pretoria [Henderson, 1998 and Henderson, 1999]. It focusses specifically on alien invasive plants, both terrestrial and aquatic. It already contains distribution data on such macrophytes as *Eichhornia*, *Azolla* and *Myriophyllum*. It does not currently include data on algae but the design of the database does not preclude this.

In essence, AGIS could potentially be used as the primary database in which algal and macrophyte occurrence can be stored. The wide range of GIS-related reporting options which AGIS provides may well satisfy the reporting needs for the NEMP for the monitoring objectives related to blooms and invasive macrophytes.

The National Coordinator would need to ensure coordination with AGIS so that it meets the needs of the NEMP in all aspects from data capture, storage and management through to reporting and other management facilities.

3.2.12 Adapting existing eutrophication monitoring programmes

Many eutrophication monitoring programmes already exist throughout South Africa. These programmes are of critical importance to the NEMP because they represent an existing capacity which in many cases is probably already fairly sustainable (because they have been designed specifically to meet local needs). These are programmes that are already up and running and therefore do not require the considerable effort of initialisation.

Each should be carefully examined to determine the degree to which they meet the minimum requirements on the NEMP (see National Monitoring Design Framework section in National Implementation chapter). If they meet these requirements, efforts should be made in consultation with the local parties responsible for the monitoring to capture the data for the NEMP. If they fall short of the minimum requirements then, depending on the nature of the shortfall and the organisations involved, an approach should be made to the local stakeholders to negotiate appropriate changes that bring it in line with the national requirements.

3.2.13 Capturing historical data

An important aspect of the first main management question addressed by a water quality catchment assessment study is "... how did it [the water-related status] get to this point?" [DWAF, 2000b]. Historical data are needed to answer this question. Furthermore, the earliest possible data can help establish baseline levels of nutrients and chlorophyll *a* which in turn help choose appropriate Resource Quality Objectives (see Local Implementation chapter).

Much historical eutrophication-related monitoring data are not captured in the national database. The National Coordinator should make every effort to initiate mechanisms to locate and capture such data. The onus would typically be on these two management levels to find the necessary resources to do this.

This may be a time-consuming task. It will depend on the amount and nature of the historical data and on the degree of compatibility between the 'external' database and the national database. Nevertheless, judgements must be made based on a comparison of the benefits of this task (particularly if historical trends are a priority objective) and the costs of doing it.

3.2.14 Sustaining commitment

It is proposed that a 'contractual win-win reward' model be implemented in order to create and sustain an appropriate culture of commitment to the NEMP, particularly among the samplers. However, DWAF would need to consider each negotiation with local stakeholders on its own merits and decide on the most appropriate model in each case. (A more detail analysis in this respect can be found in the research report associated with this manual [du Preez *et al.* 2002]). The proposed model has three primary components.

1. **Formal contracts with local agents.** For non-DWAF/CMA agents, this should be a binding contract in which the tasks to be performed are well-defined, and include when, where and how they should be performed. Most importantly, it must also be stated who takes responsibility for the local programme. Direct financial payments are then made on completion of the tasks. For DWAF/CMA employees, these contracts should take the form of formal, clear modifications to their job descriptions (in the form of key performance areas). The purpose of contractual agreements is to ensure, as far as is possible, that neither party (DWAF/CMA or the local agent) can unilaterally change the conditions of the contract. This ensures that local agents cannot simply change or terminate their involvement in the NEMP when their local priorities change.
2. **'Win-win' for DWAF/CMA and local agents.** Local agents should be chosen who themselves see direct or at least indirect benefits from involvement in the local programme. That is, they must be local stakeholders with a vested interest in the eutrophication-related water quality of the water resource. This further minimises the likelihood of a local agent not fulfilling the conditions of the contract.
3. **Reward commitment.** A system should be implemented that rewards significant commitment to sampling and creates a culture of commitment. This supplements the 'win-win' situation by further encouraging sound and frequent sampling. Some ideas on such a reward system are given in the section 'Creating and Sustaining Commitment' in the chapter The Business of Monitoring.

3.2.15 Future research needs

All water quality monitoring programmes require regular revision. One aspect that can lead to changes in current design are insights gained by relevant research. Such research should be encouraged and preferably coordinated with the express purpose of improving the NEMP design and making the information it produces more useful. This manual, in particular, should be seen as simply providing the NEMP with a kick start. As problems and new knowledge emerge, these should be dealt with and used in ways that ensure that the national objectives are still met.

The complexity of eutrophication causes and impacts will inevitably necessitate research and development that focusses on better monitoring design. This may include other indices of eutrophication and improved sampling and analytical methods and so on.

3.2.16 Increasing the relevance of monitoring data

The usefulness of monitoring information is very much a function of the capabilities of the water resource managers. Managing aquatic ecosystems is complex. Even if eutrophication management strategies exist, it should not necessarily be assumed that water resource managers will be familiar with the latest in eutrophication management practices. This is not necessarily a reflection on the competence of water resource managers but rather on the complexity of the causes and impacts of eutrophication.

The local, Water Management Area and national objectives all require eutrophication monitoring of impoundments and rivers “that is relevant to their management”. This implementation manual attempts to provide what is thought at this time to be the most relevant monitoring information (albeit in the absence of formal eutrophication management strategies). To improve and refine the relevance of the monitoring information in future, it may be necessary to develop the necessary tools for water resource managers so that they can use the monitoring information more effectively. Eutrophication management models can be developed that specifically aim at increasing the effective use of monitoring information.

3.2.17 Implementation timetable

The National Microbial Monitoring Programme (NMMP) has been successfully implemented in a phased way in which a certain number of new local programmes were implemented annually. It is proposed that the NEMP follow a similar approach.

The NEMP already has some momentum because many local monitoring programmes already exist, although they are not formally identified as part of the NEMP. Those managed by DWAF (in particular those that contributed to the Trophic Status Project, [van Ginkel *et al.*, 2000]) could easily become formal contributors to the NEMP and this should be done first. This should add tens of impoundments to the NEMP with relatively little effort.

The remaining impoundments should be chosen as described in this manual (see the Regional Implementation chapter), using the results of the prioritisation exercise. A feasible number of new impoundments should be chosen by the National Coordinator for inclusion every year. This number will depend largely on internal DWAF resources allocated to the NEMP. The National Coordinator should also decide what period of time is appropriate to achieve the ultimate aim of including all 250 impoundments in South Africa in the NEMP. It should be noted that if this period is 10 years, this requires more than 20 new impoundments to be included each year. This is a formidable task (and probably impractical) and emphasises the significant resource requirements of a complete national monitoring programme. It also highlights the need for simplicity and efficiency in initialising and sustaining new local programmes.

Given the numerous other priorities of DWAF and the many unknowns in respect of the NEMP itself (and, indeed, DWAF), it is inappropriate that this document prescribe a detailed timetable. However, the inclusion of all impoundments and important rivers and canals in the NEMP is likely to require at least 10 years and probably 15. Importantly, this assumes that sufficient resources are made available within DWAF for this purpose.

If this is coupled with monitoring programmes focussed on rivers and canals, the demands on resources increase even further.

3.3 NATIONAL MONITORING DESIGN FRAMEWORK

Meeting the national objectives requires an amount of data that may well be less than that actually collected in particular local programmes (since local objectives may, by their very nature, be more demanding). This section defines the minimum monitoring requirements from a national perspective (see **Table 3.1** for a summary).

If, for example, a local stakeholder requires an explicit prescription from DWAF of what they are required to do, then this section defines this. Any other aspect of monitoring design (like analytical methods) for national purposes are deemed to be those defined in the Local Monitoring Framework chapter (and references therein) for the associated local monitoring objective.

It is proposed that in the initial phases of implementation of the NEMP, programmes be initialised that focus primarily on the first two objectives, namely establishing current trophic status (and its recent trends) and establishing the nature of the eutrophication problems (*i.e.* blooms or macrophytes). The third objective of creating a predictive capacity is more complex and requires site-specific models to be developed. This should be introduced at a later stage.

Various extra useful variables are also defined but are not generally regarded as part of the minimum national requirements. However, there may occasionally exist site-specific conditions that make one or more of these variables essential. In such a case, DWAF can insist this be part of the minimum required.

3.3.1 Current trophic status

Trophic status is only defined in terms of a single impoundment. Therefore, the design for establishing trophic status for any impoundment for national purposes is exactly that described in the chapter Local Monitoring Frameworks. Note that a design does not exist at present for rivers.

The most critical aspects are summarised here, for convenience. The monitoring variables are chlorophyll *a* and total phosphorus concentrations. Sampling should be done using a standard 5m hosepipe if deep enough. Otherwise, use a subsurface or surface grab sample. Samples should be taken near the dam wall, or where the water is withdrawn for treatment purposes or where the sample is deemed more likely to be representative of the greater water volume. The sampling frequency is every two weeks (giving 26 samples per year). However, to allow for some missed sampling dates, an absolute minimum of 20 samples must be taken per year with at least 4 in each three month period.

3.3.2 Nature of current eutrophication problems

In essence, this objective establishes whether the eutrophication problems are related to blooms or macrophytes and, if so, what particular species and concentration.

To meet the national objectives, at least monthly visual monitoring of the water body (impoundment or river) for blooms is required and at least every three months for invasive macrophytes. If blooms are detected, phytoplankton (algal, diatom and cyanobacterial) counts and identification (typically to genus level) are required. If infestations of macrophytes are noted, then the plant species and the area that is affected are required.

Visual monitoring for blooms should performed near the dam wall or near water abstraction points (if the water is used for water treatment) or where the water may used for drinking by stock or local people. Visual monitoring for macrophytes should be done in locations most likely to contain them. For example, floating macrophytes should be monitored in a downwind direction.

3.3.3 Potential for future changes in trophic status

For the purpose of predicting potential changes in trophic status in future, exactly the same design should be used as described in the chapter Local Monitoring Frameworks (objective: long term impacts). This is a more complex monitoring objective that requires predictive modelling. This modelling will involve obtaining information on such aspects as land use, nutrient export coefficients, runoff factors, catchment size, impoundment size, nutrient balance (and hence flows and loads) and various hydrological variables. Although some of these variables are fixed, others will need to be monitored. Expert advice will need to be obtained at the time of implementation. If trophic status, *per se*, is used for model validation purposes, the identical design to that described above should be used.

3.3.4 Summary

The following table summarises the monitoring variables (“what”), the monitoring frequency (“when”) and sampling site selection (“where”) required for the national objectives to be met for a chosen impoundment, river or canal. Note that the final column of “useful variable” does not form part of what are regarded as the minimum requirements. This column merely provides some guidance on which variables that, if measured, would provide the most useful additional information.

Table 3.1. Summary of minimum design requirements for meeting the national objectives.

For the national objective ...	... the minimum requirements are ...	Other useful variables are ...
Current trophic status (impoundments only)	At least every 2 weeks TP, chlorophyll *a*, sampled at dam wall or near abstraction point.	Secchi Depth, EC, pH, Temp, DO, TN, TSS.
Nature of current eutrophication problems	*Blooms*: Monthly visual monitoring near dam wall, abstraction point or where used for drinking purposes and, if detected, phytoplankton counts and genus identification. *Macrophytes*: Three monthly visual monitoring in potentially problematic locations (*e.g.* downwind) and, if detected, species identification and area affected.	*Blooms*: cyanotoxins concentrations (if counts high), geosmin concentrations.
Potential for future changes in trophic status	Annual land use statistics, runoff factors, nutrient balance, loads etc. and as for trophic status above (*i.e*. every 2 weeks, TP, chlorophyll *a*, etc. for validation).	

3.4 NATIONAL IMPLEMENTATION PROCESS

3.4.1 Overview

A “national implementation process” is that series of actions required to set up and sustain a successful eutrophication monitoring programme throughout South Africa.

The adjacent figure shows the steps in the process. The sections that follow refer to this figure and give details of the individual steps.

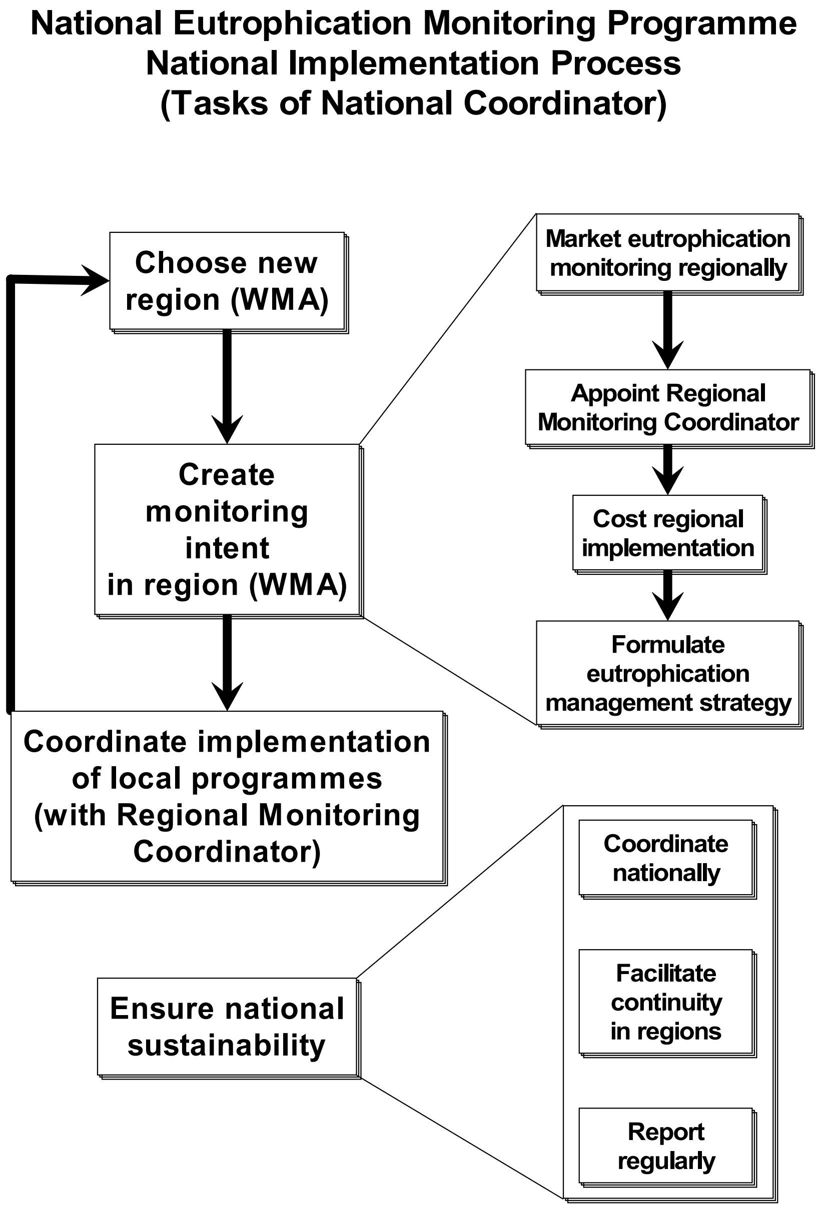


Figure 3.1. Summary of tasks in the national implementation process.

3.4.2 Choose new region (WMA)

The number of regions (Water Management Areas) should be increased in a phased manner, until, ideally all 19 areas are contributing to the NEMP. Experience will dictate the rate at which regions can be included. Targets should be set by the National Coordinator for the number of regions included in five and ten years time. The rate of inclusion should increase in later years as experience increases efficiency.

Initially, regions should be chosen with the highest chances of successful implementation of the NEMP. The criteria outlined above should be used (see section Demonstrating early successes in this chapter).

Subsequently, inclusion can be based on two criteria. First, if there is a real willingness in a region to be involved in the NEMP (irrespective of how real the regional eutrophication problems are), then these regions should be included. Secondly, in the absence of such willingness, new regions should be chosen on the basis of a prioritisation process that identifies those regions with the greatest existing or potential problems.

3.4.3 Create monitoring intent in region (WMA)

3.4.3.1 Market eutrophication monitoring regionally

Eutrophication-related monitoring does already exist in many local areas. In such cases, there already exists some degree of monitoring intent and therefore marketing of the NEMP should focus less on initialising eutrophication monitoring and more on coordinating existing efforts.

Before the establishment of formal CMAs, the National Coordinator should visit the DWAF regional offices responsible for the chosen WMA. The primary purposes are to make them aware of the NEMP and create an intent to become involved (if no monitoring exists). They should at least be given a copy of this implementation manual.

They should also be told the reasons why their WMA was chosen. A general introduction to the causes and effects of eutrophication should be given (if necessary). A summary of the various local monitoring frameworks should be presented and some preliminary discussion should ensue on the most appropriate ones.

3.4.3.2 Appoint Regional Monitoring Coordinator

A single person in the region should be appointed as the Regional Monitoring Coordinator. This person would ideally be from the DWAF regional office (prior to CMAs) or a member of the CMA (if one exists). An Assistant Regional Monitoring Coordinator should also be appointed to ensure continuity during any absence of the Regional Monitoring Coordinator.

The primary tasks of this person include managing the regional and local implementation processes (see below). This person will also be responsible for day-to-day management of the programmes subsequently (*i.e.* once up and running).

3.4.3.3 Cost regional implementation

If there are any doubts regarding potential costs, the National Coordinator should collaborate with the Regional Monitoring Coordinator and use the implementation costing model to obtain rough cost estimates for implementation in the region.

3.4.3.4 Formulate eutrophication management strategy

It is important that eutrophication management strategies be included in the overall catchment management strategy of the (current or future) CMA. The National Coordinator should work closely with the Regional Monitoring Coordinator to ensure this happens. Management strategies of other existing regions can be adapted to suit the current region. A DWAF report is available that provides guidelines for developing the water quality management component of a catchment management strategy [DWAF 2000a.]

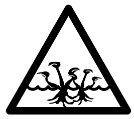
The costing estimates can be used to ensure that eutrophication monitoring is included in the following year's budget.

3.4.4 Coordinate implementation of local programmes

Although the Regional Monitoring Coordinator should be intimately involved in setting up local programmes, coordination by the National Coordinator is essential. This will ensure (1) that experience gained in other regions is effectively passed on to the new region and (2) that some degree of standardisation is achieved throughout all areas.

It is important that all local monitoring programmes are appropriately designed to meet the national objectives as well as the chosen local objectives. Local objectives are typically chosen on the basis of the local water uses (as described in the chapter on Local Implementation). The minimum requirements for meeting the national objectives are defined above (see section National Monitoring Design Framework). The following table makes explicit the links between the national design framework and the various local monitoring frameworks (see chapter Local Monitoring Frameworks). In particular, it defines which local frameworks address each of the national objectives. It is reiterated here that the responsibility for any local programme is negotiated between DWAF and local stakeholders and is *not* automatically the responsibility of DWAF.

Table 3.2. Identification of the local objectives that would address each national objective.

National objective	Local monitoring frameworks that provide the necessary data	
Current trophic status	Establish the trophic status	
Nature of current eutrophication problems	Early warning system - water treatment	
	Early warning system - blooms	
	Early warning system - invasive macrophytes	
Potential for future changes in trophic status	Early warning system - long term impacts	

3.4.5 Ensure national sustainability

3.4.5.1 Coordinate nationally

The National Coordinator should address all the issues described above (see section Implementation Issues in this chapter).

The ‘coordination’ role has two primary aims. The first aim is to enthusiastically drive the NEMP at all levels. This will be primarily at national level but with significant involvement at local level as well. The second aim is to ensure a sufficient degree of standardisation among local and regional programmes so that the national objectives are met. The emphasis of the NEMP is very much at local level. That is, local objectives are seen as a very important focus. However, it must be ensured that the local programmes are designed to meet these local objectives in a way that meets the regional and national objectives as well.

Coordination should include obtaining funding, quality control, training and the development of eutrophication models.

3.4.5.2 Facilitate continuity in regions

Monitoring programmes should be designed to be as self-sustainable as possible. However, in the initial years, active engagement by the Regional Monitoring Coordinator is likely to be significant as the local programmes are slowly made more streamlined. This means that there is likely to be a significant reliance on the Regional Monitoring Coordinator initially. Therefore, a sudden resignation (for example) of a Regional Monitoring Coordinator may have serious consequences for the continuity of the regional and local programmes. The National Coordinator must ensure that in such a case, continuity is maintained. This could be achieved by the early appointment of an Assistant Regional Monitoring Coordinator.

3.4.5.3 Report regularly

See National Water Act No 36 of 1998 Chapter 14 Section 142.

Information contained in any national monitoring system established in terms of the Water Act must be made available, subject to any limitations by law. Furthermore, reports should be presented in a format appropriate to the requirements of the intended users.

The eutrophication monitoring reports should contain colour maps of regions and South Africa as a whole. This requires computing facilities that may not exist in all regions. Therefore, it should be the responsibility of the National Coordinator to produce annual regional (WMA) reports as well as the annual national reports.

The **regional reports** should be sent to the Regional Monitoring Coordinator who can distribute them to the appropriate regional concerned parties. They should be annual and be released as soon as possible after each hydrological year (the latter appropriate to the climatic region). The purpose is to provide simple indicators of the nature and extent of the problems in the region (not all the detailed data). The regional reports will be restricted to those objectives of direct national interest.

The National Coordinator should process all total phosphorus and chlorophyll *a* data from the previous hydrological year and determine the trophic status for the currently monitored impoundments in each WMA . The trophic status should be reported in a colour-coded format on an A4 map of the WMA. Four colours should be used for the four levels of trophic status.

A separate A4 map should also be prepared which indicates the nature of any eutrophication problems. Specifically, each impoundment should be indicated with a pie chart which shows whether (1) high algal counts, (2) high cyanobacterial counts and (3) the presence of invasive macrophytes were found during the year.

The regional report should be sent to the following parties.

✓ The CMA (or DWAF regional office in the interim) for the respective WMA

✓ Other interested parties

The **national reports** should also be annual and based on all data from the appropriate hydrological years as reported annually for each of the participating WMAs.

A single national map should be added that depicts trophic status and the nature of the problems.

The report should be sent to the following parties.

✓ The Minister of Water Affairs and Forestry
✓ All appropriate DWAF directors and chief directors
✓ Department of Environment Affairs and Tourism
✓ Department of Agriculture
✓ Other interested parties

4. REGIONAL IMPLEMENTATION

This chapter should be used primarily by the Regional Monitoring Coordinator for guidance on the overall implementation process of the NEMP in a Water Management Area.

CHAPTER CONTENTS

4.1 REGIONAL OBJECTIVES

A 'region' is defined here as a Water Management Area (WMA). A Catchment Management Agency eutrophication management strategy for its associated WMA is likely to have, as a first phase, establishing the actual nature and extent of the eutrophication problem in that region. This knowledge will focus the eutrophication management strategy.

It is assumed that WMAs are sufficiently large areas for the regional objectives of the monitoring programme to be essentially identical to the national objectives (at least in general principle). For clarity, the objectives are restated below. Note that to achieve the WMA objectives, local area monitoring programmes are necessary. Combined, these could contribute to the WMA objectives. However, the local monitoring programmes and their respective objectives are dealt with separately.

National Eutrophication Monitoring Programme
DWAF or CMA
Regional (Water Management Area) Objectives

To measure, assess and report regularly on
(1) the current trophic status,
(2) the nature of current eutrophication problems,
(3) the causes of current nutrient enrichment, and
(4) the potential for future changes in trophic status
in impoundments and rivers in a Water Management Area
in a manner that will
support strategic decisions in respect of their regional management,
be mindful of financial and capacity constraints, yet,
be soundly scientific.
(What are the eutrophication problems in the WMA, how bad are they, what is causing them and what are the likely future problems?)

AND

Provide regional data that permit
national monitoring objectives to be achieved.
(What is the problem in South Africa, how bad is it and how is it changing?)

As with the national objectives, it must be made clear that these are *monitoring objectives*. Management objectives are again being implied as inevitably requiring information on "the trophic status and nature of eutrophication problems".

The management that is referred to in the objective should form part of the integrated water resources management (IWRM) of the area. Regional monitoring may also provide information for a catchment assessment study (guidelines for which appear in a recent report [DWAF, 2000b]).

It might be noted here that establishing the causes of current nutrient enrichment is included as a regional objective though it does not appear as a national objective. This is done is the spirit of providing regional authorities with as much help as possible (even, as in this case, with aspects not deemed of direct relevance to the national objectives).

4.2 IMPLEMENTATION ISSUES

4.2.1 Introduction

Just as the National Coordinator has a number of important issues to keep in mind, so does the Regional Monitoring Coordinator in the regional implementation process (described below in this chapter). Some are identical to those of the National Coordinator and the reader is referred to the National Implementation chapter for more detail.

4.2.2 Responsibilities

It is reiterated here that regional (and local) monitoring programmes should be regarded as distinct programmes in their own right with their own objectives. A regional programme *per se* (within the context of the NEMP) is *not* automatically the primary responsibility of DWAF. DWAF is likely to delegate certain tasks to the catchment management agency responsible for a particular water management area. One such task may be the establishment of a regional monitoring programme.

The emphasis given to a regional programme in this chapter is done to facilitate and simplify the establishment of such programmes *so that the national objectives are met*.

The purpose of this approach is to strive for a win-win situation whenever possible in which regional and local programmes not only address their respective objectives but those of the national programme as well. Ideally, local programmes should be designed in such a way that local, regional and national objectives are met simultaneously.

4.2.3 Regional Coordination

A single person (preferably within DWAF or ultimately the CMA) must be formally assigned the role of **Regional Monitoring Coordinator**. (See the chapter on Roles and Responsibilities for more detail on this and other roles.)

The generic role of the Regional Monitoring Coordinator is to facilitate the implementation of the NEMP in the WMA so that the regional and national objectives are achieved. The Regional Monitoring Coordinator will need to be familiar with the practical aspects of eutrophication monitoring and should be able to provide technical and managerial advice to the various role players. The Regional Monitoring Coordinator deals with the day-to-day problems in the local areas.

The Regional Monitoring Coordinator should be the driving force behind initial and ongoing implementation on a regional (WMA) basis.

4.2.4 Creating awareness

Generic mechanisms (applicable to the WMA) must be identified for conveying information on the NEMP to all regional interested parties. These should be coordinated as much as possible with those of the National Coordinator (see section Creating Awareness in the National Implementation chapter).

One such mechanism is to provide input to the regular newsletter produced by (or under the guidance of) the National Coordinator that addresses the general issues identified above for that newsletter.

4.2.5 Demonstrating early successes

The Regional Monitoring Coordinator must also implement the ‘Demonstration-for-Resource Allocation Spiral’ model. In the regional context, this will involve identifying a few local areas (*e.g.* impoundments) that satisfy the same criteria identified above for choosing initial Water Management Areas in the national implementation process (problematic impoundments identified in the prioritisation process, existing capacity, local willingness, etc.). The NEMP should then be implemented in these local areas and every effort made to achieve early success.

4.2.6 Resource requirements

The spreadsheet-based implementation costing model should be used to obtain estimates of costs to implement and maintain the NEMP in a WMA. Costs for an average local area should be used. The costs of the phased implementation of an increasing number of local monitoring programmes in the WMA can then be obtained.

Different combinations of values for variables such as the rate at which the number of local programmes is increased annually, the average number of sampling sites, the monitoring variables and so on can be investigated until the annual costs are within appropriate limits.

4.3 REGIONAL IMPLEMENTATION PROCESS

4.3.1 Overview

A 'regional implementation process' is that series of actions required to set up and sustain a successful eutrophication monitoring programme in a Water Management Area.

The adjacent figure shows the steps in the implementation process. The sections that follow refer to this figure and give details of the individual steps.

National Eutrophication Monitoring Programme
Regional Implementation Process
(Tasks of Regional Monitoring Coordinator)

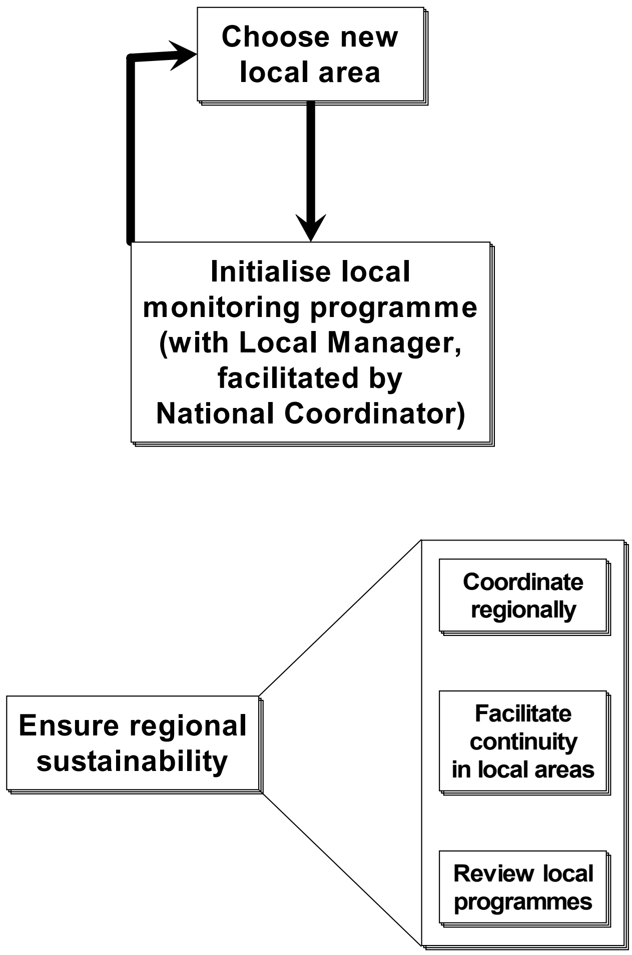


Figure 4.1. Summary of tasks in the regional implementation process.

4.3.2 Choose new local area

It is the aim of the NEMP that all South African impoundments be ultimately included in the programme. Therefore, the number of local areas (in particular, impoundments) should be increased in a phased manner, until, ideally all are contributing to the NEMP (see section Implementation Timetable in National Implementation chapter). Many impoundments already have monitoring programmes in place (though not formally part of the NEMP). For them to contribute to the NEMP they must satisfy the minimum requirements for meeting the national objectives (see chapter National Implementation).

Initially, local areas should be chosen that are known to be problematic (based on the prioritisation process) and with the highest chances of successful implementation of the NEMP. The same criteria outlined above for choosing WMAs should be used (see section Demonstrating Early Awareness in chapter National Implementation).

Subsequently, inclusion can be based on two criteria. First, if there is a real willingness in a local area to be involved in the NEMP (irrespective of how real the regional eutrophication problems are), then these regions should be included. Secondly, in the absence of such willingness, new local areas should be chosen on the basis of a the most recent prioritisation process that identified those local areas with the greatest existing or potential problems.

4.3.3 Initialise local monitoring programme

The Regional Monitoring Coordinator should initialise the implementation of local monitoring programmes (following the local implementation process described herein). This should be done in close collaboration with the National Coordinator. This will ensure nationwide standardisation and effective transfer of lessons learnt from other regions.

4.3.4 Ensure regional sustainability

4.3.4.2 Coordinate regionally

The Regional Monitoring Coordinator should address the issues described above (see section Implementation Issues in this chapter) as well as consider those directly relevant to the National Coordinator (see section Implementation Issues in chapter National Implementation).

4.3.4.3 Facilitate continuity in local areas

Local monitoring programmes should be designed to be as self-sustainable as possible. The appointed Local Managers will be responsible for local day-to-day management in particular areas. However, in the event of, for example, the resignation of a Local

Manager, a replacement person should be available immediately. This could either be a previously appointed 'Assistant Local Manager', or the Regional Monitoring Coordinator could temporarily assume the role of 'Acting Local Manager'.

4.3.4.4 Review local programmes

Each local programme should be reviewed on a regular basis to ensure that they are making the most cost effective use of resources and that they continue to satisfy the needs for which they were established. This should occur every two years following the start of each local monitoring programme.

This aspect is one mechanism of an adaptive management approach. As reports are generated and managers and stakeholders begin to use the information, they may realise that the information is inadequate. Alternatively, their objectives may change. In either case, changes may be necessary to the local monitoring design to ensure the information produced is as well focussed on the ultimate needs as possible. This is, in effect, a monitoring feedback loop [Timmerman *et al.*, 2000].

5. LOCAL IMPLEMENTATION

This chapter should be used primarily by the Regional Monitoring Coordinator and the Local Manager for guidance on the overall implementation process of the NEMP in a local area (*e.g.* a single impoundment).

CHAPTER CONTENTS

5.1 LOCAL AREA OBJECTIVES

5.1.1 Definition of objectives

Monitoring objectives for a local area are defined as follows.

National Eutrophication Monitoring Programme
DWAF or CMA
Local Area Objectives

To measure, assess and report regularly on
(1) the current trophic status,
(2) the nature of current eutrophication problems,
(3) the causes of current nutrient enrichment, and
(4) the potential for future changes in trophic status
in impoundments and rivers in a local area
in a manner that will provide support
for decisions in respect of their local management and use,
be mindful of financial and capacity constraints, yet,
be soundly scientific.
(What are the eutrophication problems in the local area, how bad are they, what/who is causing them and what are the likely future problems?)
or
Provide an early warning system
for specified eutrophication-related problems.
(Is a serious local eutrophication problem about to occur?)
or
Establish a nutrient balance.
(What/who is causing the local problem?)

AND

Provide local data that permit
regional and national monitoring objectives to be achieved.
(What is the problem in the region, how bad is it and how is it changing?)

As with the national and regional objectives, the monitoring objectives above must be distinguished from the local management (or other stakeholder) objectives. The latter objectives can in principle be much broader in context than those addressed by a single monitoring programme. A monitoring programme simply produces a well-defined ‘information product’ that may be integrated (by the manager/stakeholder) with other (possibly non-monitoring) information products to provide the ultimate information required. However, this latter process is not the direct concern of the monitoring programme *per se*.

Establishing the causes of current nutrient enrichment is included as a local objective though it does not appear as a national objective. This is done in the spirit of providing local stakeholders with as much help as possible (even, as in this case, with aspects not deemed of direct relevance to the national objectives).

In order to link the two kinds of objectives (monitoring and management/stakeholder) more explicitly, the above monitoring objectives can be further subdivided and defined, as shown in the following table.

Table 5.1. Context of local area management or stakeholder objectives.

If the local manager or stakeholder is focussed on the following aspect of current or future eutrophication ...	***Then the specific monitoring objectives that can provide relevant information are ...***	
Extent	Establish trophic status	
Nature and extent	Early warning system: Water treatment *(reasons: avoid taste & odour & filter clogging problems, minimise health risks)*	Short term
	Early warning system: Algal blooms *(reasons: avoid scums, odours, health risks due to direct use of raw water)*	
	Early warning system: Invasive macrophytes *(reasons: minimise water loss, ecological & recreational impacts)*	
Long term prediction	Early warning system: Future increase in trophic status *(reasons: mitigate or avoid future eutrophication related impacts)*	Long term
Causes	Nutrient balance	

Each of the monitoring objectives in the above table warrants a specific monitoring system design. The data thus collected may need to be combined in various ways to specifically provide for the broader local management objectives. For example, the monitoring data for ‘trophic status’ would be combined with information collected on the various short term early warning systems so that the ‘nature’ of the problem can also be reported.

It is recommended that the more complex local objectives of long term predictions and establishing a nutrient balance only be chosen in subsequent years of NEMP implementation. It is more important initially to focus on the simpler objectives of establishing trophic status and short term early warning systems.

The choice of monitoring objective depends primarily on the stakeholder objectives. It is important to understand the difference between a 'monitoring objective' and a 'stakeholder objective'. A stakeholder objective relates to goals or aims from a stakeholder's perspective. This perspective may be much broader than simply water quality or eutrophication *per se*. The stakeholder may often be a water resource manager. However, it could also be an organisation or person that uses the water in a particular way (like for water treatment or recreation). However, such a stakeholder perspective may require (among other types of information) knowledge of water resource quality as might be affected by eutrophication. Then a 'monitoring objective' that provides a well-defined information product (which may be a report) that contains such information becomes the purpose of the local monitoring programme. It is one of a number of potential information products that stakeholders might need to meet the stakeholder's objectives. In essence, a stakeholder objective will usually be a higher level objective which can only be met with a series of information products, some of which may be identified as monitoring objectives.

It is critically important that a dialogue is created between the information user (the stakeholder) and the information producers (those choosing and implementing the particular local monitoring programme) [Timmerman *et al.*, 2000]. This dialogue will typically revolve around the objectives of the stakeholders and ultimately result in one or more monitoring objectives being agreed upon. The stakeholder should agree that the monitoring objective (in particular, its information product) will help address the stakeholder's objectives. Only the stakeholder can judge this properly. On the other hand, the information producer must agree that the chosen monitoring objective is sufficiently well-defined and scientifically and financially feasible. Only the information producer (*i.e.* the designer of the local monitoring programme) can properly judge this.

5.1.2 Responsibilities

Meeting the national objectives of the NEMP is the responsibility of the Department of Water Affairs (DWAF). Local monitoring programmes should be regarded as distinct programmes in their own right with their own objectives (noted above). Importantly, these local programmes are *not* automatically the sole responsibility of DWAF (although data collected by them will be the data that meet the national objectives). However, DWAF may choose to make a local programme its responsibility if, for example, it is required to meet the national objectives and no local stakeholders can be found. In such a case, DWAF can take full responsibility for the local programme. In general, responsibilities will be negotiated between DWAF (typically represented by the National Coordinator) and the local (and possibly regional) stakeholders.

The detailed emphasis given to local monitoring programme designs in this manual is done to facilitate and simplify the establishment of such programmes *so that the* *national objectives are met*. Specifically, these recommended designs can be presented to local stakeholders as points of departure upon which actual designs can be negotiated. This is particularly relevant if local stakeholders are not yet doing their own monitoring. Consultation and negotiation can then proceed. The National Coordinator will ensure that the minimum requirements for meeting national objectives are in place (see chapter National Implementation). A mutually beneficial decision should then be made on exactly who takes what responsibilities. This should form the basis of a formal contract between DWAF and the local parties.

The purpose of this approach (of providing recommended local designs) is to strive for a win-win situation whenever possible in which local programmes not only address their own local objectives but those of the national programme as well. Ideally, local programmes should be designed in such a way that local, regional and national objectives are met simultaneously.

5.1.3 Resource Quality Objectives

Stakeholder objectives usually depend on the nature of the local pollution sources and what the water is being used for. If the local stakeholder is DWAF, then, for example, the water uses (current and future) will determine the 'desired state' (the Resource Quality Objectives, RQOs) of the water body. This can be defined in terms of the 'water resource class'. This is a formal classification procedure that is strictly outside the scope of this manual. The latest procedures should be obtained from DWAF. How the RQOs will be established must be decided by the concerned parties and appropriate actions implemented.

The stakeholder (in this case, management) objective might then assume that monitoring will be performed to enable the current state of the water body to be compared with the RQOs. This enables quantitative auditing of management actions.

If formal procedures for establishing the RQOs are not available, then guidance should be obtained from DWAF on the most appropriate course of action. One option may be to simply define the RQOs as the current state. This, at the very least, will provide a management objective that will ensure that the water resource does not worsen in respect of eutrophication. When formal procedures become available, they can be properly implemented to define more appropriate RQOs.

5.2 LOCAL IMPLEMENTATION PROCESS

5.2.1 Overview

A 'local implementation process' is that series of actions required to set up and sustain a new eutrophication monitoring programme in a local area. The National Coordinator and Regional Monitoring Coordinator should coordinate this process. The following figure shows the steps in the process. The sections that follow refer to this figure and give details of the individual steps.

The figure refers to the situation where no local eutrophication monitoring exists in the chosen local area. However, many local monitoring programmes do already exist throughout South Africa. Typically these have been created to address local objectives and many are managed by (and currently the sole responsibility of) local stakeholders. These programmes are invaluable to the NEMP because they represent monitoring intent, local capacity and expertise *already in place*. This means that initialisation of the local programmes (from scratch) is unnecessary. Therefore, certain steps in the local implementation process (as depicted in the figure) need not be carried out.

If a local eutrophication monitoring programme is known to exist, those responsible for it should be approached by the Regional Monitoring Coordinator (or National Coordinator). The national objectives of the NEMP should be discussed with them and the degree to which the existing programme can contribute be examined. In particular, it should be established to what degree the minimum requirements of the national programme (see National Implementation chapter) are already met. If these are met, efforts should be made to register the programme formally within DWAF and capture the data. Negotiation (and a formal contract) will be necessary.

If the local programme does not meet minimum NEMP requirements, then negotiation will be necessary to implement changes that bring it in line with these requirements. Again, a formal contract is necessary.

National Eutrophication Monitoring Programme
Local Implementation Process
(Local tasks of Regional Monitoring Coordinator)

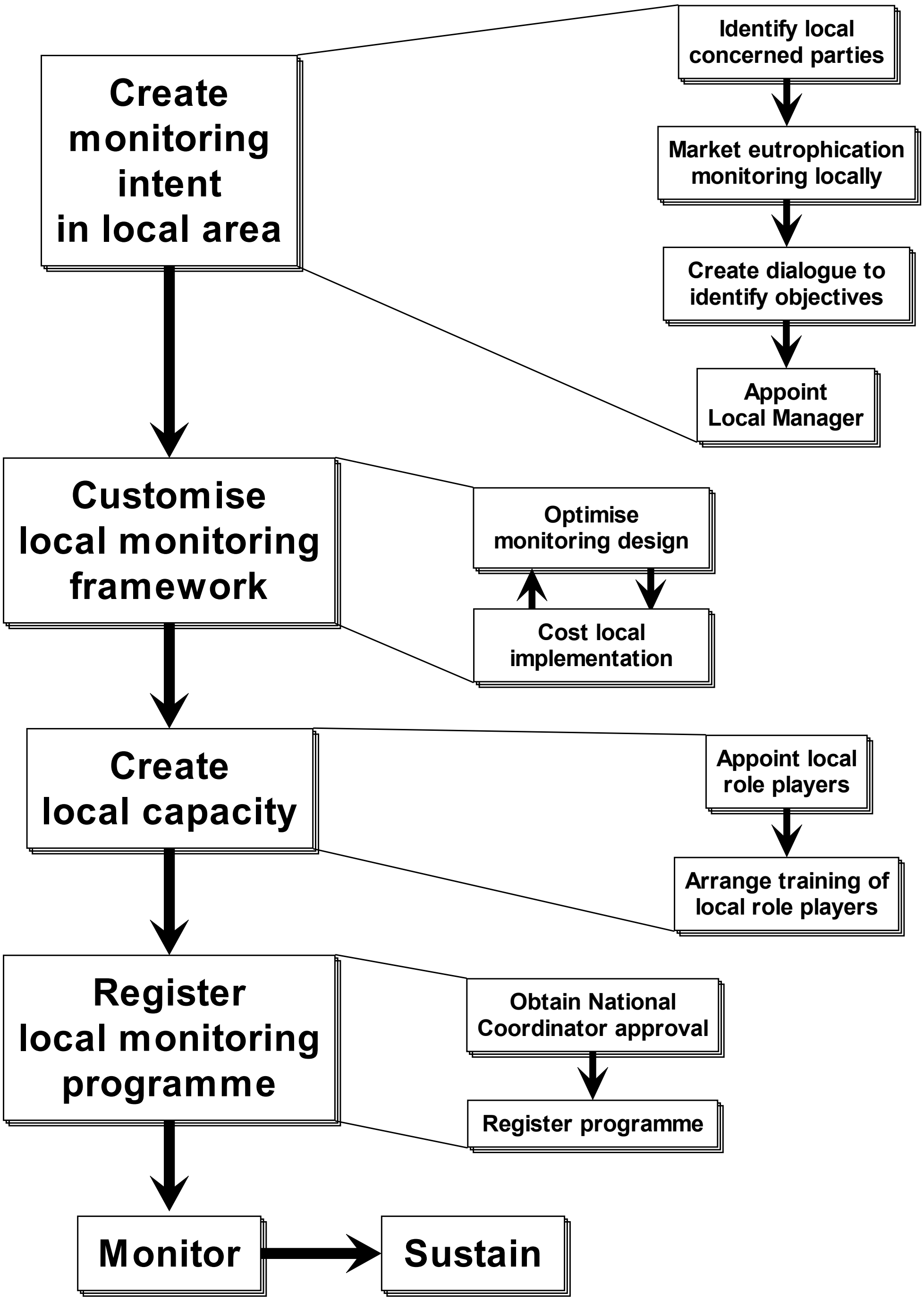


Figure 5.1. Summary of tasks in the local implementation process.

5.2.2 Create monitoring intent in area

5.2.2.1 Identify local concerned parties

The Department of Water Affairs and Forestry has the primary responsibility to implement a national eutrophication monitoring programme for surface waters. However, the involvement of local concerned parties is likely to be to the advantage of all involved.

Specific water management institutions, water user associations and public organisations (for example, boating or fishing clubs) exist in many areas. They may well have interests that overlap with those of the National Eutrophication Monitoring Programme. An important management question in a water quality catchment assessment study is "who are the water-related stakeholders and institutions in the study area and what are their respective jurisdictions, relationships, linkages, and roles?" [DWAF, 2001]. That report describes how this question can be answered and it should be consulted for guidance in this step of the local implementation process of a local eutrophication monitoring programme.

In general, a guiding principle is to identify those local concerned parties that would have an inherent vested interest in a monitoring programme. That is, their involvement in the local programme would be a 'win-win' situation.

5.2.2.2 Market eutrophication monitoring locally

It may be necessary to 'sell' (or at least explain) the concept of eutrophication and monitoring thereof to prospective concerned parties. This may initially be the responsibility of the Department of Water Affairs and Forestry (in particular, the National Coordinator). However, it may also become the responsibility of the Regional Monitoring Coordinator in order to create and sustain interest and the necessary support.

Various tools can be used, depending on the specific audience. The following are some examples.

1. The systems model diagrams of causes and impacts of eutrophication (in Chapter 2 of this manual). (These provide a generic summary of the driving forces of eutrophication and a summary of the main negative impacts.)
2. References to the Water Act (No. 36 of 1998) and the Water Services Act (No. 108 of 1997). Many such references are made in this manual. (These will explicitly convey the statutory requirements of people and organisations associated with water, *i.e.* what they have to do by law.)
3. The diagrams showing the 'Local Implementation Process', the 'Regional Implementation Process' and the 'National Implementation Process'. (This will demonstrate the steps required to get a new local programme off the ground. It will also demonstrate that the local programme is an important part of a larger

regional and national programme.)

4. Copies of the implementation costing can be made available. (This will enable all role players and concerned parties to see who is contributing and how much.)

Besides the above, when some local programmes are up and running, the annual national reports can be shown to illustrate the use to which the data has been put.

It is important that marketing of the NEMP is done well. A professional marketing person or organisation should be employed to develop an appropriate marketing strategy and implement specific marketing drives.

5.2.2.3 Create dialogue to identify objectives

To ensure appropriate focus and standardisation of all subsequent activities, it is important to identify (and have consensus among all concerned parties) on the exact objective that a local monitoring programme should address. Each monitoring objective is listed in **Table 5.1** above and described in detail in the chapter 'Local Monitoring Frameworks'.

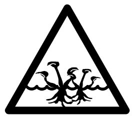
Important background information on the broader context of Water Quality Assessment Studies can be obtained from the document 'A Guide to Conduct Water Quality Assessment Studies: In support of the Water Quality Management Component of the Catchment Management Strategy' [DWAF, 2001]. In particular, the following two components should be consulted.

- Water Quality Requirements and Constituents of Concern
- Record of Water Quality Issues and their Origins

The most appropriate monitoring objectives must be chosen for each local area. More than one can be chosen. However, it should be noted that if two or more are chosen, a separate monitoring programme is required for each objective. Of course, it may be possible to overlap certain aspects of each in practice. However, each should be regarded (at least conceptually) as a completely separate exercise.

Some guidance for choosing monitoring objectives based on the way the water is used (in the water body or downstream) is given in the adjacent table.

Table 5.2. Guiding criteria for choosing objectives for local monitoring programmes based on the water use.

If your local impoundment, river or canal is used for this purpose ... ↓	... then appropriate local monitoring programme objectives might be the following:			
	Establish trophic status (impoundments)	Short term early warning systems (impoundments, rivers, canals)		
		Water treatment	Algal blooms	Invasive macrophytes
				
Domestic	✓		✓	
Recreational	✓		✓	✓
Livestock watering	✓		✓	
Irrigation	✓		✓	✓
Aquaculture	✓		✓	
Aquatic ecosystems	✓		✓	
Water treatment		✓	✓	

Establishing the trophic status is recommended in almost every case (for impoundments) because this is the simplest measure of the degree of eutrophication.

5.2.2.4 Appoint Local Manager

Having identified the concerned parties in the region, it is necessary to appoint a person (typically from one of the concerned parties) to take on the responsibility of being the Local Manager. That person may also manage a number of programmes in nearby areas. To ensure continuity in the absence of the Local Manager, an Assistant Local Manager should also be appointed.

All concerned parties should be requested to submit nominations for the Local Manager. The choice of Local Manager should be based on the following criteria:

- ❑ The candidate should have sufficient time and capacity to carry out the tasks. The percentage of time and other resources required should be estimated as part of the implementation costing exercise.
- ❑ The candidate's superiors should be completely satisfied with the allocation of the local managers time and other resources to the monitoring programme. Ideally,

the job description of the Local Manager should define the tasks and the time allocated to them.

- ❑ The candidate should have sufficient expertise and experience to enable successful implementation and ongoing management of the local programme.
- ❑ The candidate should be motivated and committed to the objectives of the local (and national) programmes and have a vested interest in the results.

5.2.3 Customise local monitoring framework

5.2.3.1 Optimise monitoring design

Examine the recommended monitoring design framework in the chapter 'Local Monitoring Frameworks' and the minimum requirements for meeting the national objectives (see National Implementation chapter). Negotiation between the Local Manager, the Regional Monitoring Coordinator and the National Coordinator (the latter representing DWAF) should take place on the following.

- ❑ The number of sampling sites and their locations
- ❑ The sampling or monitoring frequency taking all the necessary issues into account.

Responsibilities for each task should be decided and recorded in a contract that binds all parties. In the case of an existing local monitoring programme, modifications to the programme (if any) should be negotiated that bring it in line with the minimum national requirements.

5.2.3.2 Cost local implementation

If there are any doubts about the monitoring costs, the Regional Monitoring Coordinator in consultation with the Local Manager (and the National Coordinator, if necessary) and any potential resource providers should perform an implementation costing for the single local area and the chosen monitoring objectives. An Excel spreadsheet interface can be obtained from DWAF for this purpose.

If costs are found to be excessive, then return to optimising the monitoring design until costs are within reasonable limits.

5.2.4 Create local capacity

5.2.4.1 Appoint local role players

The Local Manager and the Regional Monitoring Coordinator need to formally assign the appropriate organisations and people to each of the roles from sampler through to data transmitter (if they do not already exist). Relevant sections of the implementation costing can be supplied to these parties if necessary so that they are fully aware of the cost implications for them, if any. Appropriate contracts should be drawn up and/or job descriptions modified accordingly.

5.2.4.2 Arrange training of local role players

Some training may be necessary to ensure that, for example, the correct sampling and analytical techniques (like phytoplankton counts) are being applied. When, where such training will occur and the associated costs must be decided and arranged.

5.2.5 Register local monitoring programme

5.2.5.1 Obtain National Coordinator approval

Particularly in the initial few years of implementation in any one region, the Regional Monitoring Coordinator must seek approval of the local monitoring programme implementation framework from the National Coordinator. The primary aims of this step are as follows.

- ✓ To ensure nationwide standardisation of NEMP implementation. (This is one of the first steps in overall quality assurance.)
- ✓ To provide an opportunity for the National Coordinator to ensure that the design avoids known pitfalls and problems that may have occurred elsewhere (that the Regional Monitoring Coordinator may not be aware of).
- ✓ To keep the National Coordinator informed of progress.

This step should be streamlined to ensure that local implementation is not delayed in any way. The Regional Monitoring Coordinator must send the following:

- ❏ Approval form with customised monitoring framework.
- ❏ Implementation costing (either the spreadsheet file or hardcopies).

Templates for the approval forms for each objective are given in an appendix.

5.2.5.2 Register programme

Each local monitoring programme involving sampling and laboratory analysis needs to be formally registered with DWAF. To do this, send the following:

- ❑ Completed Monitoring Programme Registration forms obtained from DWAF.
- ❑ An A4 or A3 copy of a 1:50 000 scale map of the area. The photocopy must contain (i) the scale on the edge of the original map, (ii) the map number (e.g. 2734AB), (iii) the map name (written clearly if not on the photocopy), (iv) each sampling site circled and numbered.
- ❑ Information on all the sampling sites including sampling site number, description (so that someone else can find the site easily), name of water body, longitude, latitude, station number (if site is in an existing monitoring programme). An Excel spreadsheet is available from DWAF for this purpose if necessary.

5.2.6 Monitor

Upon successful registration, DWAF will send a schedule to each sampler confirming exact sampling details (location, frequency, delivery etc.). Sample bottles suitably tagged (again with sampling details) will also be provided by DWAF, if DWAF is doing the analyses. Once the programme is registered on the DWAF Water Management System, actual monitoring can begin.

5.2.7 Sustain

The Local Manager, Regional Monitoring Coordinator and National Coordinator should coordinate efforts to ensure the local monitoring programme is sustained. Problems must be solved promptly to ensure local continuity. The Local Manager should rely on the expertise of the Regional Monitoring Coordinator and National Coordinator for advice.

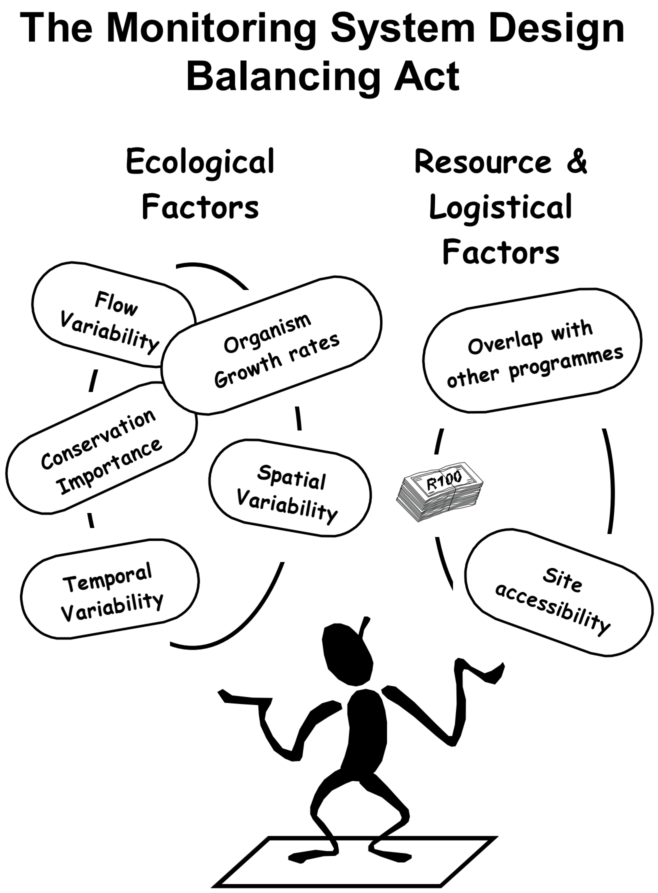
Regular (*e.g.* annual) workshops should be organised in each region which the Regional Monitoring Coordinator and local stakeholders (and preferably the National Coordinator) should attend. Problems can be presented and discussed and local monitoring programmes reviewed. Such meetings will help motivate those involved and build team spirit.

6. LOCAL MONITORING FRAMEWORKS

This chapter should be used primarily by the Regional Monitoring Coordinator and the Local Manager for designing detailed monitoring programmes for a local area (*e.g.* a single impoundment) once the monitoring objectives have been identified.

CHAPTER CONTENTS

6.1 INTRODUCTION



Each local monitoring programme must be specifically designed to (1) address the identified local objective, (2) take local ecological and resource factors into account and (3) satisfy the minimum requirements for meeting the national objectives (see National Implementation chapter). Designing monitoring programmes is a highly specialised assignment. Local monitoring programmes *per se* are not automatically the sole responsibility of DWAF. However, to facilitate good design of local programmes, this chapter looks beyond the minimum requirements for the national programme and provides two main types of information. First, it describes the many generic factors in monitoring design that need to be considered, irrespective of the precise local objective. Secondly, it provides specific frameworks for each local objective that can be used as points of departure. The reader is nevertheless encouraged to consult relevant literature (referenced herein) or local expertise for more detail should this be deemed necessary.

6.2 GENERIC DESIGN CONSIDERATIONS

6.2.1 Introduction

Irrespective of the precise management objective, there are many aspects of monitoring system design that are entirely generic. The following sections summarise these generic issues. These should be thoroughly considered before proceeding to a design for any specific management objective. Typically, the designer of a monitoring system performs a balancing act between available resources on the one hand and ecologically sound factors on the other.

In general, the recommendations contained herein focus on the minimum required to provide the necessary information (for the specified objective). However, it should be recognised that eutrophication is a complex phenomenon and that, in general, the more data one has the better are the chances of a sound understanding of the situation. Therefore, if it is easy and cheap to do more than the required minimum then this should be done. (For example, in some circumstances the measurement of variables like pH and conductivity may not be recommended as high priority. However, pH and conductivity meters are cheap and easy to use and hence such measurements can often easily be included.) However, it is important not to take this philosophy so far that one creates a ‘data rich - information poor’ situation. The extra variables must be useful variables.

All monitoring programmes should also be reviewed on a regular basis to ensure that they are making the most cost effective use of resources and that they continue to satisfy the needs for which they were established.

6.2.2 Overlap with existing programmes

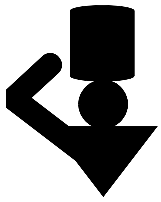
Potential overlap with other monitoring programmes must be considered in some detail. Existing programmes may already be collecting samples in the area of interest. Given the high costs of sampling (compared to all other costs associated with a national or regional monitoring programme), being able to ‘piggyback’ on other sampling rounds (and even sharing the costs) will contribute to significant savings. This may even allow extra sampling sites to be chosen beyond those that would have been possible if piggybacking was not done.

Notwithstanding the enormous cost-saving advantages of such piggybacking, the precise design of the other monitoring programme must be examined in detail. It must conform sufficiently well to the design contained within this manual in all aspects from sampling and analytical methods through to sampling frequency, site selection and quality control. A loss of standardisation in monitoring design can have significant implications for the subsequent interpretation of data. If any loss of information is anticipated through use of an ‘external’ monitoring programme, this must be clearly defined, the ramifications understood and made clear to all concerned.

The Department of Water Affairs and Forestry is currently involved in a number of national programmes that monitor surface waters.

The National Chemical Monitoring Programme monitors chemical variables (some of which include eutrophication-related variables like N and P) at an enormous number of sampling sites in rivers and impoundments.

The River Health Programme (the National Aquatic Ecosystem Biomonitoring Programme) is primarily focussed on the ecological state of aquatic ecosystems [Murray, 1999]. The emphasis has also tended to be on river ecosystems. Biomonitoring is the gathering of biological information in both the laboratory and the field for the purpose of making an assessment or decision or in determining whether water quality objectives have been met. This monitoring programme does not monitor eutrophication directly. However, if an ecosystem is impacted due to eutrophication (or any other cause) then the decrease in ecological integrity would be likely to be reflected in one or more biomonitoring indices. There are indices for invertebrates, fish, riparian vegetation, habitats and geomorphology. Each is at a different stage of development with the most commonly used index being SASS5 (for invertebrates).



The National Microbial Monitoring Programme is primarily focussed on monitoring faecal pollution of surface waters and determining the associated human health risk [Murray, 2000]. An increasing number of local monitoring programmes is being implemented each year. This programme measures faecal coliforms, turbidity, pH and temperature on a weekly basis.

6.2.3 Visual monitoring

Visual monitoring *in situ* is recommended below for early detection of blooms and spread of invasive macrophytes (to avoid various ecological and other impacts) and as a backup or supplement to sampling for water treatment purposes.

Two variables are monitored. First, the presence or absence of any phytoplankton blooms (either algal, diatom or cyanobacterial though not necessarily identified) or specified macrophytes is noted. Secondly, the extent of the area affected is visually estimated.

It is assumed that the visual monitoring will usually be done by non-experts (*e.g.* at best Water Control Officers at DWAF impoundments). Monitoring *in situ* should therefore be facilitated by the development and distribution of a small publication (brochure) containing good colour photographs.

There should be regular monitoring by officers specifically trained for the purpose. However, to supplement this, members of the public who use the water resource on a regular basis can also be encouraged to report unusual events. These might include fishermen or sailing and boating enthusiasts and even bird watchers and hikers. Even South African Airways pilots have been known to report blooms [D van Driel, 2000, Cape Metropolitan Council, personal communication]. Although involving the public increases the chances of false identifications, these can be followed up and confirmed by an appropriately qualified person.

It is acknowledged that it is sometimes very difficult for a non-expert to, for example, distinguish between green algal scums and those due to cyanobacteria. However, identification of macrophytes is easier.

Incidents can be reported by phoning a relevant authority (at a phone number on a brochure used for identification purposes) or by recording the incident on a web site specifically designed for the purpose. AGIS (described above) may be able to be used for this purpose.

The officer responding to an incident report can also take the necessary water samples (in the case of blooms) and ensure these reach a laboratory as soon as possible for positive identification.

Regional DWAF officers are often overloaded and will therefore not be able to respond to each and every incident report. A screening process for incident reports is necessary in order to avoid either crank calls or those of little or no real concern.

The area affected by either a phytoplankton bloom or an invasive macrophyte should be estimated visually *in situ*. The actual area is considered an appropriate reporting statistic since this can be estimated by non-experts more easily than, say, percentage coverage in the case of an impoundment (which can, in any case, be obtained easily subsequently from the actual coverage and the total impoundment surface area). See chapter Procedure Specifications, section Visual Area Estimation.

6.2.4 Sampling site selection

The location and number of sampling sites is always a critical aspect in the design of a monitoring system. The following are some factors that influence the choice of sites.

- **Available resources** is one of the most important factors affecting the number of sampling sites and their precise locations. Before proceeding with the selection of individual sites, perform a preliminary costing exercise. Establish the approximate number of sampling sites that can be reasonably managed with the available resources. Then proceed to consider the other factors determining site selection.

- The **health and safety** of people monitoring and sampling should be carefully considered. If there is any potential danger from wild animals, local people, any local hazard (like steep slopes) or even toxic algae, appropriate steps should be taken to minimise the risk, including choosing another sampling site (if appropriate).

- A fundamental ecological factor to consider is whether the water quality variables are **conservative or non-conservative**. A non-conservative variable can vary in amount as a result of a number of processes which cause it to change independently of how much was originally added to the water.

This is in stark contrast to conservative variables. Salts like sodium, chloride and so on accumulate along the length of a watercourse in the direction of flow as a result of additional inflows. Amounts added at the most upstream point are usually still present when the water passes the most downstream point. Their concentrations are only reduced by such mechanisms as dilution and adsorption on solid surfaces.

A variable such as the concentration of algae is non-conservative because algae are living organisms that grow and decay over time as local conditions change (like nutrient and light availability). Sites would typically be chosen where growth is likely to be highest. The nutrients used by the algae should also be regarded as non-conservative variables.

- The location of algal scums floating on the surface of water bodies will tend to move according to **wind direction** and accumulate near the banks of the water body in the downwind direction. In the case of visual monitoring, the sites chosen for monitoring may need to take wind direction into account. If routine sampling of the water body is taking place, then the sampling site would typically remain at the site(s) originally chosen, irrespective of wind direction.

- In general, **local spatial variability** (at any one time) in the water quality variables typically associated with eutrophication can be significant even in a single water body.

  Excessive phytoplankton growth is often associated with **slow moving water bodies**, as typically occurs in impoundments.

  In an impoundment spatial variability occurs vertically, laterally and longitudinally. Vertical variability is invariably caused by seasonal stratification (and destratification) of the water body. South African impoundments are mostly monomictic (*i.e.* overturn of the water occurs once a year in the autumn) [Toerien *et al.*, 1975]. Thereafter the water is well mixed throughout the winter until late spring (late September or early October). The highest concentrations of nutrients may therefore be expected in the surface layers some time after turnover and before stratification occurs. (High concentrations can also be caused at other times by high rainfall events and flooding).

  There are also surface effects which can be avoided by taking sub-surface samples. Considerable differences also occur between the edges of the impoundment and the centre. If only a single sample can be taken in an impoundment then this should be at a position near (but preferably not next to) the dam wall in the centre of the upper surface area about 15 cm below the surface or using a 5 m hosepipe. This clearly requires a boat to provide access. If this is not possible, then the sample should be taken at the dam wall at the centre. Vertical profiles can be considered if the expense is justified.

Bear in mind that some phytoplankton species can occur in layers. For example, if one occurs in the top 10 cm, a composite sample down to 5m may indicate that there is not a significant problem. In such cases, it may be important to ensure that visual monitoring (and the appropriate recording of observations) supplements the sampling so that the problem is actually detected.

Spatial variability can also be significant in rivers though this is typically less of a problem than in impoundments.

- If any analyses need to be carried out within a specified time after sampling, these **analytical time constraints** may create logistical problems. Sites may need to be chosen that allow the sample to reach the laboratory in time.

- The sampling site should be **characteristic of local conditions**. A sample should be representative, because it is being presented as evidence of the quality of the water body from which it is obtained.

- The site should be **easily accessible** to the person taking the sample. Valuable time and resources are wasted if this is not the case. Sampling is an expensive item in an overall monitoring programme. Considerable attention should be given to making it as efficient as possible.

- Ideally, **spatial correlation** should not occur between samples taken at different sites. This means that a sample at one site should not vary in composition in a way that can be predicted from the composition of a sample taken at some nearby sampling site. This will occur if there is no significant change in conditions in the watercourse and if no additional pollution sources occur between the two points. If correlation occurs, then resources are being wasted because the second sampling site is not providing information that cannot be obtained from the first site.

- Sites should be chosen so that they take account of **seasonal variations** and other variations over time. The flow of water in a watercourse is less in dry seasons so, for a constant pollution source, pollutant concentrations will be higher. On the other hand, wet seasons result in greater surface runoff. Therefore pollution arising from runoff will be greater. High rainfall events also cause sudden increases in pollution levels.

6.2.5 Sampling frequency

> ***Caution 1***: Preferably do not describe frequency with terms involving the prefix 'bi'. For example, the word 'biweekly' means BOTH 'every two weeks' AND 'twice a week' [Collins Shorter English Dictionary, 1994]! Rather use the explicit phrases 'fortnightly' or 'every two weeks' and 'twice a week' (or 'twice-weekly'). Note that even 'two-weekly' could be misinterpreted so avoid this as well.
>
> ***Caution 2***: When specifying dates any format is acceptable that is totally unambiguous. In particular, make sure that the reader can distinguish between the month and the day. For example, write Jan 5 2002.

Determining the optimum sampling frequency requires consideration of a number of factors.

- The greater the **variation in seasonal flow**, the more frequently monitoring should occur. In the case of rivers particular, it has been suggested that if the ratio of maximum to minimum flow in a river is greater than 100, then weekly sampling for conservative variables is appropriate. A river with a well-regulated flow can have minimum monitoring, say monthly [Sanders et al. 1987]. Similarly, the greater the anticipated **variation in water quality** (for whatever reason), the greater the frequency.

- A variable being monitored may be a living organism itself (like an alga) or be dependent on living organisms (like chlorophyll *a*). The monitoring frequency must necessarily depend on the **growth rates of organisms**. The faster the organism concentration changes naturally the more frequent the sampling will need to be. For example, if a particular algal species can grow significantly in one week, then weekly sampling may be required to detect it so that appropriate management actions can be implemented. (This is not an issue for conservative substances like many chemical variables such as sodium, sulfate, and so on.)

- If observations are taken close enough together in time (like daily), the observations may exhibit **serial correlation** (*i.e.* be closely related) [Sanders et al. 1987]. This means that there may be some degree of redundancy in successive observations. (Statisticians use a so-called 'autocorrelation function' to characterise this correlation.)

- In an area in which there is a **lack of data** upon which to make statistical decisions on sampling frequency, it may be appropriate to adopt a frequency that is high (say weekly) for an initial period (say one year). After this initial intensive monitoring period the data can be analysed to establish whether this frequency can be relaxed. Ideally this analysis should be done by a competent statistician who is conversant with the specific monitoring objectives in that area.

- The **risk** of eutrophication-related problems should be established if possible.

The higher the risk the more frequently sampling should be done.

- It is important that frequency be **balanced against the associated costs**.

An 'ecologically optimum sampling frequency' is defined here as the minimum frequency (i.e. that with the longest time between sampling) that provides sufficient information for the specified objective, irrespective of costs.

If the required resources preclude such frequent monitoring, then less frequent monitoring can be adopted. However, the manager must realise that the decreased information content may contain inherent risks. For example, short-lived impacts (that come and go between sampling rounds) may not be detected. The consequences of this must be considered and explicitly accepted. The optimum sampling frequency can therefore be regarded as a 'negotiable' recommendation. However, the consequences of the decreased information content must be understood and acknowledged.

In a sense, this is a typical risk management scenario. Risks are minimised at the optimum ecological sampling frequency. Less frequent sampling increases the risk. If this increased risk is acceptable to the manager (*i.e.* he/she is prepared to take this risk and accept the consequences), then the less frequent sampling is adopted.

The following figure schematically illustrates the dependence of information content on sampling frequency. It assumes that the ecologically optimum sampling frequency has been determined to be weekly for the hypothetical management objective. (It is not being implied that weekly is the most appropriate generic frequency in practice.)

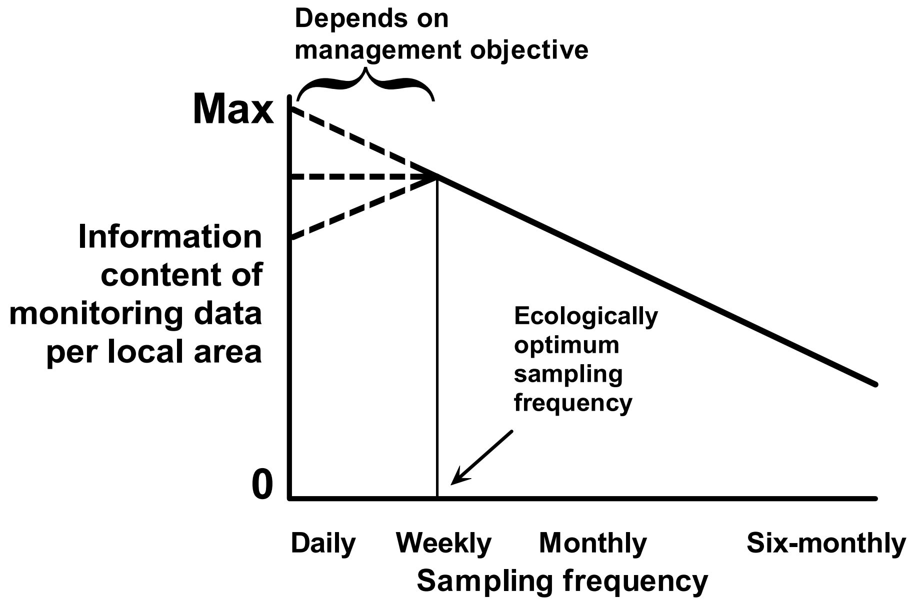


Figure 6.2. Schematic illustration of the relationship between information content and sampling frequency.

- **Local knowledge** of phytoplankton bloom history and a good understanding of local growth conditions will greatly enhance the capacity to anticipate bloom formation. Such knowledge should be used whenever possible [Chorus and Bartram, 1999]. As knowledge and understanding of a given water body accumulate, regular patterns of algal or cyanobacterial growth may be noticed. In the long term, monitoring may be focussed upon critical periods and locations.

6.2.6 Data assessment and reporting

Assessment (assumed to include a degree of 'value addition' to the presentation of the basic data) of eutrophication monitoring data can be performed at various levels. The most appropriate methods should be chosen for the identified management objectives.

The data can be displayed and presented in various ways. Further information (with examples) can be obtained from the component 'Water Quality for Streamflow, Reservoirs, Estuaries, Wetlands and Groundwater' in the document 'A Guide to Conduct Water Quality Assessment Studies: In support of the Water Quality Management Component of the Catchment Management Strategy' [DWAF, 2001]. The following presentation options can be considered.

- Summary statistics (average, median, minimum, maximum, standard deviation and number of samples).
- GIS maps for synoptic overview.
- Times series plots.
- Annual box-and-whisker plots.
- Seasonal box-and-whisker plots.

- Exceedence diagrams.
- Flow-concentration plots.
- Concentration versus distance diagrams.

At the very least, data for the various monitoring variables can be compared with the South African water quality guidelines [DWAF, 1996a-g], if they exist. These will provide some information on the fitness for each specified use.

The following table summarises the current guidelines for some of the variables of interest to eutrophication. It is essential that the original guideline documents be examined carefully to ensure that the various terms are properly understood and the guidelines are correctly interpreted.

Table 6.2. Summary of South African water quality guidelines for some variables related to eutrophication.

	Target Water Quality Range							
	Algae	**Ammonia**	**Dissolved Oxygen**	**Nitrate/ Nitrite**	**Nitrogen (Inorganic)**	**Phosphorus (Inorganic)**	**Turbidity**	**pH**
		mg NH_3/ℓ	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**NTU**	**pH**
Aquatic ecosystems		≤0.007	80-120%[1]	see N (inorg)	<15%[1]	<15%[1]		±0.5 or <5%[1]
Domestic (Human Consumption)	0-1[1] 0-50[2] 0-0.8[3]	0-1.0		0-6(NO_3 or NO_2)			0-1	6-9
Recreation (Full Contact)	0-15[1] 0-6[4]						≥3.0[1]	6.5-8.5
Recreation (Intermediate Contact)	as for full contact							
Industry (Category 1)			Not relevant					7.0-8.0
Industry (Category 2)			Not relevant					6.5-8.0
Industry (Category 3)			Not relevant					6.5-8.0
Industry (Category 4)	Not relevant		Not relevant					5-10
Agriculture (Livestock Watering)	<6.0[4] <2000[5]			0-100(NO_3) 0-10(NO_2)				
Agriculture (Irrigation)				see N (inorg)	0-0.5[2]			6.5-8.4
Agriculture (Aquaculture)		0-0.025[1] 0.0-0.3[2]	6-9[2] 5-8[3]	0-0.05(NO_3)		≤0.1	≤25[2]	6.5-9.0

Algae: 1 = μg/ℓ chl *a*; 2 = blue-green algal cells/mℓ; 3 = μg/ℓ microcystin; 4 = Blue-green algae colonies/0.5 mℓ counted in a 2 minute scan at 200x magnification; 5 = *Microcystis* cells/mℓ
Ammonia: 1 = cold water species; 2 = warm water species
Dissolved Oxygen: 1 = of saturation; 2 = cold water species; 3 = intermediate and warm water species
Nitrate/Nitrite: 1 = for each of nitrate and nitrite;
Nitrogen: 1 = (as for phosphorus); 2 = irrigation equipment
Phosphorus: 1 = from that of the water under local unimpacted conditions at any time of the year **and** trophic status must not increase above its present level **and** the amplitude and frequency of natural cycles in inorganic phosphorus concentrations should not be changed.
Turbidity: 1 = Secchi disk depth (m); 2 = Clear water species
pH: 1 = of background pH values for a specific site and time of day

6.3 OBJECTIVE-SPECIFIC DESIGN FRAMEWORKS

> ***The local frameworks recommended in this section are appropriate for impoundments and rivers with the one exception that trophic status refers only to impoundments (not rivers).***

6.3.1 Introduction

It is important that the intention of the monitoring frameworks described in the following sections be understood clearly. ***The following monitoring frameworks are broadly-based generic recommendations that should be used as a point of departure in the design of a monitoring programme for any particular local area.*** Site-specific conditions and available resources will determine the degree to which these recommendations are actually adopted (or, equivalently, the degree of departure from them) by local stakeholders. A negotiation with DWAF will be necessary. The minimum requirements from DWAF's point of view for the national programme are those prescribed in the National Implementation chapter. These would typically be the limit of DWAF's responsibility. It is reiterated here that local programmes are not automatically the responsibility of DWAF.

6.3.2 Objective: Establish the trophic status

6.3.2.1 Introduction

At a local level, knowing the extent of the problem (as represented by the 'trophic status') in an impoundment is likely to be a primary interest of the managers of that impoundment and of stakeholders directly *affecting or affected by that water body*. However, it is important that the design of any such local monitoring programme be such that it can feed directly into the regional (WMA) objectives (and ultimately the national objectives).

One of the first management questions in a water quality catchment assessment is "what is the water-related status of the study area ..." [DWAF, 2000b]. The objective of establishing trophic status addresses this directly.

It is important that the limitations of trophic status are understood. Since trophic status is primarily based on chlorophyll *a* concentrations in the water column, it is a measure of *planktonic* algal and cyanobacteria (not of attached algae and macrophytes). Furthermore, the relationships between trophic status and chlorophyll *a* and total phosphorus concentrations have only been shown to work well for impoundments. They are not yet tested for rivers [WR Harding, 2000, Southern Waters, personal communication]. Given the typically high flow rates (and hence low residence times) and general variability of conditions in rivers, it is therefore recommended that trophic status only be measured in impoundments. (The eutrophication status in rivers should rather be obtained from the other monitoring procedures.)

Trophic status can be used to monitor the effects of subsequent remedial actions such as attempts to reduce nutrient loadings into the impoundment.

6.3.2.2 Monitoring objective

Local, regional and national: To determine and annually report on the trophic status of an impoundment (i.e. the extent of the problem).

6.3.2.3 Monitoring variables

Trophic status is established using **chlorophyll *a*** and **total phosphorus** concentrations. These are therefore the primary variables that should be monitored. Additional variables which are useful from a management perspective include **Secchi Depth**, **electrical conductivity**, **total nitrogen**, **total suspended solids**, **pH**, **temperature**, **dissolved oxygen** (site specific).

6.3.2.4 Sampling procedures

Use a 5 m hosepipe if deep enough. If not deep enough and if convenient access to the water is possible, use a subsurface grab sample. Otherwise use a surface grab sample.

6.3.2.5 Sampling site selection

Ideally the samples should be taken near the dam wall or where the water is withdrawn for treatment purposes or where the sample is deemed more likely to be representative of the greater water volume. The relationships between chlorophyll *a*, total phosphorus and trophic status were based on samples taken near the dam wall [Walmsley and Butty, 1980], so this position is preferable.

6.3.2.6 Sampling frequency

In order to provide a good indication of the fluctuations over an annual period, it is recommended that samples be taken at least every two weeks [Walmsley and Butty, 1980].

6.3.2.7 Data management

Since all monitoring data are measured using standard laboratory techniques, all should ultimately reside on WMS (Water Management System) at DWAF. If the analyses are performed at any laboratories other than the laboratory at DWAF, a strategy must exist that ensures the data is transmitted to the National Coordinator. This can be by fax or (preferably) spreadsheet file. Remote entry of the data directly into WMS may also become possible. When this is so, this is preferable.

6.3.2.8 Quality control

QC Data quality objectives

To (a) provide a sufficient number of measurements of adequate quality per year to enable an accurate determination of the trophic status and (b) to ensure that the data quality can be recorded for data assessment and reporting purposes.

QC Roles and responsibilities

The primary responsibility for local quality control lies with the Regional Monitoring Coordinator who should either personally perform the necessary tasks or allocate them to a suitably reliable and trained representative.

QC Data collection

1. At least 1 in every 20 samples taken (5%) should be subject to complete duplication (from actual sampling through to analysis and data capture) by the person doing the routine sampling. Analysis of the quality control sample should be done by an accredited laboratory, or at least one that takes part in inter-laboratory studies that has been shown to be reliable.
2. At least once a year this duplicate sample should be taken (and prepared and preserved) by a suitably competent and experienced person (reporting to the Regional Monitoring Coordinator) different from the person doing the routine sampling. All quality control samples should be taken at the same time and place as the routine samples.

QC Data evaluation

Trophic status requires not only accurate data but also a sufficient number of measurements per year. Since 26 samples per year are required ideally, it is recommended that (a) 20 or more samples be analysed for the data to be regarded as sufficient and (b) there should be at least four samples in each of the following three-month periods: January to March, April to June, July to September and October to December.

Sampling methods, sample preparation and sample preservation should be visually checked at least twice each year by the Regional Monitoring Coordinator (or appropriate representative).

QC Systems and performance reviews

The Regional Monitoring Coordinator and/or the national coordinator should review all quality control data on an annual basis. Two aspects should be checked: First, all necessary quality control samples should have been analysed and their data captured. Secondly, the reviewer should check the data quality and quantity using the above data evaluation guidelines.

If insufficient quality control data have been determined, then all the data should be flagged as having ‘insufficient quality control’ in a way that this is clear to the person doing the ultimate data assessment.

If either fewer than 20 samples were analysed or there were fewer than 4 samples in any three-month period, the ultimate reporting of trophic status should reflect ‘insufficient data’.

If the analysis of the quality control data indicates poor quality data (*i.e.* they do not agree within reasonable experimental error), all data should again be flagged as having ‘insufficient quality control’.

If comparisons between analytical results and quality control results are satisfactory, the data should be flagged as ‘data reliability good’.

QC *Corrective actions*

If comparisons between analytical results and quality control results are unsatisfactory then corrective actions must be put in place to, first, determine the cause of the discrepancy and, secondly, ensure the discrepancy does not arise again.

The first action is to advise the agents responsible for sampling, analysis and data capture that a problem has been detected. Discussions with them may be sufficient to determine the cause of the problem.

If such discussions do not reveal the possible cause of the problem, personal visits to the sampling site (with the sampler) and/or the laboratory may be necessary. In each case, the procedures used should be carefully examined and recommendations made if necessary.

In such a case, it is advisable to collect a quality control sample as soon as possible after problems are thought to be corrected. The ultimate data from this sample should be examined as soon as it becomes available to ensure that the problem has indeed been solved.

QC reports to management

The results of each annual quality control data evaluation exercise should be documented in a format that can be made available to any person who may perform any form of data assessment.

6.3.2.9 Data assessment and reporting

Annually, use the measured data to determine the following three statistics.

Mean annual chlorophyll *a* (µg/ℓ)
Percentage of time chlorophyll *a* > 30 µg/ℓ (%)
Mean annual total phosphorus

Using the adjacent table and each of the three statistics, describe the trophic status narratively as indicated.

Table 6.3. Narrative descriptions of trophic status statistics for reporting purposes.

Statistic	Unit	**Current trophic status:**			
Mean annual chlorophyll *a*	µg/ℓ	$0<x\leq 10$	$10<x\leq 20$	$20<x\leq 30$	>30
		Oligotrophic (low)	**Mesotrophic (moderate)**	**Eutrophic (significant)**	**Hypereutrophic (serious)**
		Current nuisance value of algal bloom productivity:			
% of time chloropyll *a* > 30 µg/ℓ	%	0	$0<x\leq 8$	$8<x\leq 50$	>50
		negligible	**moderate**	**significant**	**serious**
		Potential for algal and plant productivity:			
Mean annual Total Phosphorus	mg/ℓ	$x\leq 0.015$	$0.015<x\leq 0.047$	$0.047<x\leq 0.130$	>0.130
		negligible	**moderate**	**significant**	**serious**

For example, if the three statistics were 25, 5 and 0.2 respectively, then the following description would be reported.

Current trophic status: Eutrophic (significant)
Current nuisance value of algal bloom productivity: moderate
Potential for algal and plant productivity: serious

Also report the number of samples on which each statistic is based and the assessment of the data quality (as determined by the quality control procedures).

6.3.2.10 Management

Trophic status and its trends can be used to obtain a general picture of the state of eutrophication in impoundments. Resource quality objectives could be defined in terms of the desired trophic status or any of the variables mentioned above.

The South African water quality guidelines [DWAF, 1996a-g] can be used to define a basic Threshold of Potential Concern. This is when one or more of the following occur.

- ❑ When the Total Phosphorus at any time of the year, deviates by more than 15% from that under local unimpacted conditions (at that time of year).
- ❑ The trophic status has increased (*e.g.* a previously mesotrophic impoundment is now eutrophic)
- ❑ The amplitude or the frequency of Total Phosphorus natural cycles are significantly changed (>15%)

If any of the above occur, it may be necessary to investigate the causes of the problem.

6.3.3 Objective: Early warning system - water treatment

6.3.3.1 Introduction

There exists a wide spectrum of water treatment processes and scales (in terms of volumes of water treated). At the one extreme, large water boards (like Umgeni Water and Rand Water) typically have significant resources and capacity to perform extensive monitoring in order to anticipate potential problems when the quality of their raw water changes. These organisations have tried and tested monitoring programmes that are seen as beyond the scope of this project. However, at the other extreme, there are other organisations (like small water boards and metropolitan councils) that treat water on smaller scales and that have considerably less resources and capacity. This section targets these organisations.

Typically, the eutrophication-related problems experienced in water treatment involve taste and odour problems (usually associated with geosmin), filter clogging and the potential for toxicity due to cyanotoxins. When small algae and diatoms are present, filter penetration can also be problematic.

6.3.3.2 Monitoring objective

Local: To detect the presence of algal, diatom or cyanobacterial blooms so that negative impacts on a local water treatment works (or the ultimate treated water quality) are avoided or minimised.

Regional and National: To provide information on the nature of eutrophication problems.

6.3.3.3 Monitoring variables

Laboratory analyses should include **phytoplankton (algal, diatom and cyanobacterial) counts and identification** (typically to genus level). Should the cyanobacterial counts be sufficiently high, then analyses for **cyanotoxins** and **geosmin** can be carried out, though this is optional and will depend on local requirements and available resources.

Visual monitoring of presence or absence of blooms should be regarded as an essential backup to the above routine sampling and analyses. This is particularly so if such sampling cannot be done at the recommended frequency. If a bloom is suspected then samples should be taken at the bloom site as soon as possible for a **phytoplankton count and identification** of the nature of the bloom (algal, diatom or cyanobacterial). The person performing the visual monitoring must have sampling equipment available on each visit to the site.

6.3.3.4 Sampling procedures

Use a 5 m hosepipe if deep enough. If not deep enough and if convenient access to the water is possible, use a subsurface grab sample. Otherwise use a surface grab sample.

6.3.3.5 Sampling site selection

Ideally samples should be taken at or close to the abstraction point.

If resources permit, samples can also be taken from specific depths. This will allow the vertical distribution of the phytoplankton population in the water column to be established. This knowledge can be used to select the most appropriate depths at which to draw off water so that water with the minimum population density is used.

6.3.3.6 Sampling frequency

In general, sampling every two weeks for phytoplankton counts and identification is recommended until a problem is encountered, after which it should be more frequent. In low risk water bodies, even monthly sampling is satisfactory.

More frequent sampling will reduce the risk and increase the time available to modify the treatment process (like purchase and prepare for activated carbon treatment). Less frequent sampling (like monthly) will increase the risk. The ultimate frequency chosen is very likely to be primarily determined by available resources.

More frequent visual monitoring for the appearance and persistence of blooms should be investigated. This is particularly so if the recommended weekly sampling frequency is beyond the resources of the organisation. If blooms are detected or suspected, samples can be taken and the presence confirmed.

6.3.3.7 Quality control

QC Data quality objectives

To ensure that samples are taken sufficiently frequently and representatively to be useful as an early warning system and that samples are analysed sufficiently accurately so that the monitoring objectives are achieved

QC *Roles and responsibilities*

The primary responsibility for quality control lies with the local manager who should either personally perform the necessary tasks or allocate them to a suitably reliable representative. The local manager has the primary responsibility because it is the local stakeholder that benefits in the first instance from the local monitoring programme. The early warning system is their ‘return on investment’.

QC Data collection

The overall system of sampling, analysis and reporting (to the water treatment works) must be efficient. Tests must be devised that check that when a bloom actually begins to form, the sample is taken representatively, is analysed quickly and accurately, and the results reach the appropriate decision maker so that timely action can be taken within the works to minimise the impacts of the bloom. The accuracy of phytoplankton counts and identification should be checked by sending split samples to other reliable laboratories for comparison.

QC Data evaluation

The results of the test (accuracy and efficiency) should be carefully examined to ensure that the system sampling through to reporting is adequate for providing an early warning system. The whole process will need to be reduced to a few days or so for it to be useful.

QC Systems and performance reviews

The local manager should examine the QC data immediately after it has been collected.

QC Corrective actions

If the efficiency of the overall system is inadequate, then steps should be taken to identify the bottleneck and then avoid it occurring in future.

If comparisons between analytical results and quality control results (of the phytoplankton counts and identification of split samples) are unsatisfactory, then corrective actions must be put in place to, first, determine the cause of the discrepancy and, secondly, ensure the discrepancy does not arise again.

The first action is to advise the agents responsible for sampling and analysis that a problem has been detected. Discussions with them may be sufficient to determine the cause of the problem.

If such discussions do not reveal the possible cause of the problem, personal visits to the laboratory may be necessary. In each case, the procedures used should be carefully examined and recommendations made if necessary.

In such a case, it is advisable to collect a quality control sample as soon as possible after problems are thought to be corrected. The ultimate data from this sample should be examined as soon as it becomes available to ensure that the problem has been solved.

QC reports to management

The results of each quality control data evaluation exercise should be documented in a format that can be made available to any person who may perform any form of data assessment. At a regional and national level, the efficiency of the early warning system is only of secondary concern. Of primary concern is the accuracy of the analyses.

6.3.3.8 Data assessment and reporting

If a sample is actually taken when monitoring visually, the arrival of the sample itself at the laboratory should serve as the early warning signal for the relevant concerned parties. A mechanism must be in place to ensure this (since analyses and communication of the results can take some time).

6.3.3.9 Management

Resource quality objectives could be defined in terms of the desired phytoplankton counts, identification, cyanotoxins or geosmin. The organisation responsible for the water treatment is likely to play an important role in determining these resource quality objectives. They will be defined at levels that minimise negative impacts on the water treatment process and the quality of the final treated water.

Actions in response to a warning that a problem is occurring (or has occurred) can vary. They may include using alternative water sources if possible. If this is not possible then the water treatment process may need to be modified to take account of the specific problem anticipated. This may include the *ad hoc* use of activated carbon.

6.3.4 Objective: Early warning system - blooms

6.3.4.1 Introduction

For current purposes, blooms include those of green algae, diatoms and cyanobacteria.

Of primary concern in respect of blooms is the fact that in many rural areas and informal settlements in South Africa, people make direct use of raw or partially treated water for domestic and other purposes. Animals, both domestic and wild, (including fish) also make direct use of raw waters. In these water resources, the appearance of toxic (*i.e.* cyanobacterial) blooms presents a potential health risk to both animals and humans. The presence of a bloom is likely to be more of a health risk for animals than humans because humans will tend not to use the water if there is an obvious problem. However, impacts on humans have been recorded [Chorus and Bartram, 1999] and where local communities may still use the water, the risk obviously remains.

The implementation of a monitoring system for the specific purpose of detecting blooms can also be used to supplement monitoring for water treatment purposes. However, ***the current objective specifically differs from the water treatment objective from the point of view that <u>direct use</u> of the contaminated raw water is possible unless users are prevented from doing so***.

The appearance of green algal and diatom blooms (as opposed to cyanobacterial blooms) will tend to have negative ecological, aesthetic, recreational impacts (which in turn can have economic impacts). They also have direct negative economic impacts for water treatment plants (though generally not health impacts). Scums that may form are unsightly and their decay can produce unpleasant odours. Ecological impacts include lowering oxygen levels (particularly in the hypolimnion) and decreasing biodiversity.

6.3.4.2 Monitoring objective

Local: To detect the presence of algal, diatom or cyanobacterial blooms so that negative impacts due to <u>direct use</u> of the water by local people or animals can be avoided or minimised. (Note that this objective is not aimed at preventing the occurrence of the bloom itself.)

Regional and National: To provide information on the nature of eutrophication problems.

6.3.4.3 Monitoring procedures

Routine **visual monitoring** on a weekly basis is recommended (aimed at early detection of blooms) throughout the year. If a bloom is suspected then samples should be taken at the bloom site as soon as possible for a **phytoplankton count and identification** of the nature of the bloom (algal, diatom or cyanobacterial). At other times of the year, visual monitoring can be done on a monthly basis. The person performing the visual monitoring must have sampling equipment available on each visit to the site.

After a bloom has been identified, visual monitoring, sampling and analysis should continue on at least a weekly basis (or at a frequency appropriate to any remedial actions invoked). This will monitor natural changes in the algal, diatom or cyanobacterial species populations as well as the effectiveness of the remedial actions.

6.3.4.4 Quality control

QC Data quality objectives

To ensure that samples are taken sufficiently frequently and representatively to be useful as an early warning system and that samples are analysed sufficiently accurately so that the monitoring objectives are achieved

QC *Roles and responsibilities*

The primary responsibility for quality control lies with the local manager who should either personally perform the necessary tasks or allocate them to a suitably reliable representative. The local manager has the primary responsibility because it is the local stakeholder that benefits in the first instance from the local monitoring programme. The early warning system is their ‘return on investment’.

QC Data collection

The overall system of sampling, analysis and reporting (to the water treatment works) must be efficient. Tests must be devised that check that when a bloom actually begins to form, the sample is taken representatively, is analysed quickly and accurately, and the results reach the appropriate decision maker so that timely action can be taken within the works to minimise the impacts of the bloom. The accuracy of phytoplankton counts and identification should be checked by sending split samples to other reliable laboratories for comparison.

QC Data evaluation

The results of the test (accuracy and efficiency) should be carefully examined to ensure that the system sampling through to reporting is adequate for providing an early warning system. The whole process will need to be reduced to a few days or so for it to be useful.

QC Systems and performance reviews

The local manager should examine the QC data immediately after it has been collected.

QC Corrective actions

If the efficiency of the overall system is inadequate, then steps should be taken to identify the bottleneck and then avoid problems occurring in future.

If comparisons between analytical results and quality control results (of the phytoplankton counts and identification of split samples) are unsatisfactory, then corrective actions must be put in place to, first, determine the cause of the discrepancy and, secondly, ensure the discrepancy does not arise again.

The first action is to advise the agents responsible for sampling and analysis that a problem has been detected. Discussions with them may be sufficient to determine the cause of the problem.

If such discussions do not reveal the possible cause of the problem, personal visits to the laboratory may be necessary. In each case, the procedures used should be carefully examined and recommendations made if necessary.

In such a case, it is advisable to collect a quality control sample as soon as possible after problems are thought to be corrected. The ultimate data from this sample should be examined as soon as it becomes available to ensure that the problem has been solved.

QC reports to management

The results of each quality control data evaluation exercise should be documented in a format that can be made available to any person who may perform any form of data assessment. At a regional and national level, the efficiency of the early warning system is only of secondary concern. Of primary concern is the accuracy of the analyses.

6.3.4.5 Data assessment and reporting

Data can be compared with the South African water quality guidelines [DWAF 1996a-g] for the relevant water use.

If a sample is actually taken when monitoring visually, the arrival of the sample itself at the laboratory should serve as the early warning signal for the relevant concerned parties. A mechanism must be in place to ensure this (since analyses and communication of the results normally take some time).

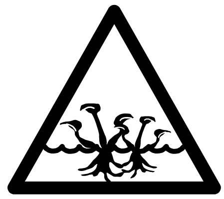
6.3.4.6 Management

Resource quality objectives could be defined in terms of the desired degree to which blooms occur and their nature.

In the case of cyanobacterial blooms, the most immediate management action is to warn potential water users of the dangers and provide an alternative water source. These include farmers who might use the water for stock watering, recreational users who might expose themselves directly to cyanobacteria (*e.g.* while swimming or skiing) and local communities who may use the water for domestic use. It should be noted that simply putting up signs may not be sufficient to ensure that people do not use the water (irrespective of how well the message is communicated by the sign).

For more detailed management information on cyanobacteria, consult Chorus and Bartram (1999). Physical controls include destratification, light exclusion for small facilities and scum coralling. Nutrient deprivation, biological control and the use of algicides (though not if they rupture cyanobacteria and cause the release of toxins into the surrounding water) are also options. The strategy of choice will eventually depend on the physical characteristics of the water body and the use to which it is subjected [Holdsworth, 1991]. It has been noted that because some cyanobacteria can fix atmospheric nitrogen, control of nitrogen appears to have limited value in eutrophication control [Toerien *et al.*, 1975].

6.3.5 Objective: Early warning system - invasive macrophytes



6.3.5.1 Introduction

Floating macrophytes are problematic because they increase water losses through evapotranspiration, they inhibit oxygen transfer from the atmosphere and light penetration into the water body, they can inhibit surface mixing and generally lower the capacity of an impoundment to improve the quality of inflowing waters. Water hyacinth (*Eichhornia crassipes*) is the world's worst aquatic weed [Hill and Cilliers, 1999]. The problems in the Hartbeespoort Dam in the mid-seventies are legendary and the attempts at control at that time and subsequently, are well documented [*e.g.* Scott *et al.*, 1979, Hill and Cilliers, 1999]. Established mats of water hyacinth can also act as ideal breeding grounds for mosquito larvae and protect the snail vector of bilharzia, therefore posing a health hazard.

Submerged and rooted macrophytes (like parrot's feather, *Myriophyllum aquaticum*) can be problematic because they can clog waterways, especially rivers and canals, block water extraction pumps and interfere with recreational activities [Cilliers, 1999].

Notwithstanding the above-mentioned potential problems, many macrophytes are highly desirable and sometimes essential elements of natural ecosystems. Any 'problems' associated with a particular macrophyte should be carefully weighed against potential advantages to the ecosystem as a whole.

Some specific plants regarded as problematic are shown in the adjacent table.

Table 6.4. Some problematic macrophytes in South Africa.

Common name	Scientific name	Approximate invaded area (ha) [Versveld *et al.*, 1998]
Water hyacinth	*Eichhornia crassipes*	676 500
Red water fern	*Azolla filiculoides*	6 000
Kariba weed	*Salvinia molesta*	3 000
Parrot's Feather	*Myriophyllum aquaticum*	1 000
Water lettuce	*Pistia stratiotes*	500
Saw-weed	*Najas pectinata*	
Duck weed	*Lemna gibba*	

6.3.5.2 Monitoring objectives

Local: The primary objectives are (1) to monitor the extent of significant problematic infestations of invasive macrophytes and (2) detect the establishment of new areas as early as possible so that appropriate local management actions can be taken as quickly as possible.

Regional and National: To provide information on the nature of eutrophication problems.

The ultimate objective is to prevent infestations that reach proportions that will (1) have unacceptable ecological, aesthetic, recreational and economic impacts and (2) require excessive resources to remove.

6.3.5.3 Monitoring variables

Visual inspection of impoundments should be carried out to determine (1) the **presence or absence** of specified plants and, if present, (2) the **area** that they cover.

6.3.5.4 Monitoring site selection

The location of floating plants in impoundments is dependent on wind direction since plants will tend to accumulate along the perimeter in the downwind direction. Ideally, an impoundment should be examined along the whole perimeter. However, since this is difficult and time-consuming in many cases, the points from which the assessment is made should be in the downwind direction and should take into account the shape of the dam.

In the case of submerged and rooted macrophytes, the extent (area) of infestation at known sites should be monitored.

6.3.5.5 Monitoring frequency

Impoundments should ideally be monitored on a monthly basis throughout the year.

6.3.5.6 Quality control

QC Data quality objectives

To ensure that visual monitoring is done sufficiently frequently and representatively to be useful as an early warning system and that identifications are done sufficiently accurately so that the monitoring objectives are achieved

QC *Roles and responsibilities*

The primary responsibility for quality control lies with the Regional Monitoring Coordinator who should either personally perform the necessary tasks or allocate them to a suitably reliable representative.

QC Data collection

The overall system of sampling, analysis and reporting must be efficient. Tests must be devised that check that macrophytes are correctly identified and that the results reach the appropriate decision maker so that timely action can be taken.

QC Data evaluation

The results of the test (accuracy and efficiency) should be carefully examined to ensure that the system sampling through to reporting is adequate for providing an early warning system. The whole process will need to be less than two weeks for it to be useful.

QC Systems and performance reviews

The Regional Monitoring Coordinator should examine the QC data immediately after it has been collected.

QC Corrective actions

If the efficiency of the overall system is inadequate, then steps should be taken to identify the bottleneck and then avoid problems occurring in future.

The first action is to advise the agents responsible for montoring that a problem has been detected. Discussions with them may be sufficient to determine the cause of the problem.

If such discussions do not reveal the possible cause of the problem, personal visits may be necessary. In each case, the procedures used should be carefully examined and recommendations made if necessary.

QC reports to management

The results of each quality control data evaluation exercise should be documented in a format that can be made available to any person who may perform any form of data assessment. At a regional and national level, the efficiency of the early warning system is only of secondary concern. Of primary concern is the accuracy of the analyses.

6.3.5.7 Data assessment and reporting

The South African water quality guidelines deal specifically with plants that can endanger the safety of and impinge on the physical comfort of recreational water users [DWAF, 1996b]. This section summarises those guidelines.

Plant growth can pose a physical hazard in recreational water by entangling swimmers, water skiers and board sailors. In addition it can be nuisance to anglers through snagging of tackle. In extreme cases water bodies can become unusable for recreation.

The inevitable decay of dead plants can give rise to odours and render the water unaesthetic if excessive amounts are present. A water body choked up with prolific plant growth, like water hyacinth, is less aesthetically enjoyable than one that is free from such growth.

The growth of aquatic vascular plants in water bodies for **full contact recreation (swimming)** 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. They also 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.

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, waterskiers and boardsailors.

Aquatic plant growth should not detract from the aesthetic aspects of water bodies 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.

6.3.5.8 Management

Resource quality objectives could be defined in terms of the desired macrophyte species composition and the abundance (as measured by the area covered).

The control of aquatic macrophytes can be approached in a number of ways. Mechanical means include dredging and physical harvesting [see, for example, Wiechers *et al.*, 1996]. Chemical means have included spraying of herbicides. Biological means include the release of animals or insects that destroy the plants in one way or another. For example, the introduction of the exotic Chinese carp (*Ctenopharyngodon idella*) has been used to control the submerged macrophyte *Potamogeton pectinatus* [Versveld *et al.*, 1998] though different opinions exist on whether this should be encouraged. Biological control has also been used for *Eichornia crassipes* [Hill and Cilliers, 1999] and *Myriophyllum aquaticum* [Cilliers, 1999].

As noted above, many macrophytes are essential ecosystem components. Furthermore, over control of macrophytes can often invoke a change from macrophyte to microphyte (algal, diatom or cyanobacterial) dominance in a system, potentially creating a different set of more difficult problems. Considerable care should therefore be exercised to ensure an appropriately holistic management solution is implemented.

6.3.6 Objective: Early warning system - long term impacts

6.3.6.1 Introduction

Certain changes in land use practices can lead to increased nutrient enrichment and hence eutrophication. It may be deemed necessary to determine whether existing trends or planned changes in land use practices might cause longer term eutrophication problems. The time scale in this context is assumed to be years.

This monitoring objective inevitably involves predictive modelling. Further information in this regard can be obtained from the component 'Configured and Calibrated Water Quality Predictive Tools/Models' in the document 'A Guide to Conduct Water Quality Assessment Studies: In support of the Water Quality Management Component of the Catchment Management Strategy' [DWAF, 2001]. This document addresses, among other questions, "where might the water quality status of the study area be heading in the future?". This current monitoring objective deals with this in a eutrophication context.

6.3.6.2 Monitoring objectives

Local, Regional and National: To detect the potential for future changes in trophic status.

6.3.6.3 Monitoring variables

For rough predictions of potential eutrophication problems in the longer term, it is possible to monitor current changes in (or use predicted values for) the land areas associated with specific uses (residential, industrial, rural, etc.) upstream of the water body of interest. Using established nutrient export coefficients (kg/(ha.yr)), runoff factors and established models it is possible to predict such parameters as phosphorus, nitrogen and chlorophyll *a* concentrations in receiving waters.

Other factors such as catchment size, impoundment size and various hydrological variables can also be taken into account.

Including measurements of flow allows a nutrient balance to be established as well as making the monitoring programme load-based (instead of concentration-based). This improves the predictive capacity. (See the section describing the framework for establishing a nutrient balance in this chapter for more information.)

Although this is a more complex local objective, all these variables can be used to develop a predictive modelling capability that will allow managers to be more proactive than when only concentration-based data is used (such as forms the basis of trophic status).

The degree to which such monitoring requires actual sampling of the water body will depend partially on the degree to which the model needs to be validated. The NEMP objective of monitoring trophic status will automatically provide data on total phosphorus and chlorophyll *a*. This can be supplemented with total nitrogen if this was included in the modelling exercise.

If the validation is successful, then the model can be used to predict future concentrations (and hence potential eutrophication). If future problems are anticipated, appropriate measures can be initiated to avoid the problem. Longer term monitoring systems in sensitive areas can also be initiated that monitor the trophic status and its trends to ensure that the problems have indeed been avoided by the measures taken.

6.3.6.4 Sampling procedures

As for monitoring trophic status.

6.3.6.5 Sampling site selection

As for monitoring trophic status.

6.3.6.6 Sampling frequency

As for monitoring trophic status.

6.3.6.7 Quality control

As for monitoring trophic status.

6.3.6.8 Data assessment

Data can be compared with the South African water quality guidelines [DWAF 1996a-g] for the relevant water use.

6.3.6.9 Management

This is the only local objective that is exclusively based on establishing a predictive capacity (as opposed to simply reporting the current state and recent trends). This therefore allow a degree of proactive management not achievable with the other local objectives. Management actions will typically focus on either avoiding the anticipated land use changes or on providing for adequate management of runoff or emissions from the problematic areas.

6.3.7 Objective: Nutrient balance

6.3.7.1 Introduction

This monitoring objective will usually be fairly localised in nature. If a specific water body is found to have eutrophication problems that need to be addressed, the causes of the problem will need to be established (if not already known). In this way, focussed mitigation measures can be introduced that directly address the root of the problem.

On a more long term basis, it may be deemed necessary to monitor loads into and out of sensitive impoundments. This can help understand the internal mechanisms that may have caused a eutrophication problem. It can also help isolate the external sources primarily responsible for increased nutrient loads. This is particularly so if multiple inputs exist (for example, many streams flowing into an impoundment).

It is important to note that this is an existing objective within the Directorate for Water Quality Management in DWAF. They have prescribed processes to deal with sampling and analysis that, for example, take account of the possible need for legal action. They should be consulted for the latest details. The following sections therefore only summarise the issues briefly.

6.3.7.2 Monitoring objectives

Local: To quantitatively establish the sources and ultimate destinations of nutrients in a local water body so that the causes of nutrient enrichment can be identified.

Regional: Primarily to identify the main sources of nutrient enrichment.

6.3.7.3 Monitoring variables

Determining the origin of nutrient enrichment will typically involve the determination of the nutrient loads (kg/day) entering the impoundment of interest from various sources. This requires the measurement of **flow**. Since the focus of this objective is specifically nutrients, **total nitrogen** and **total phosphorus** are the most important variables.

6.3.7.4 Sampling procedures

It is possible that suspected polluters (individuals or organisations) may need to be approached and presented with evidence of their contributions to the eutrophication problem. Typically, the Directorate for Water Quality Management in DWAF would play this role. It is also possible that such evidence may be contested by the suspected polluter. In this case it will be essential that sampling procedures are carried out very soundly. Statistical analyses may also be necessary.

In such cases, it is advisable that replicate samples at each site are taken at each sampling round and analysed, preferably at different laboratories.

If legal action is inappropriate, then single samples are likely to be sufficient.

An important quality assurance task is the careful calibration of flow metres.

6.3.7.5 Sampling site selection

Using a combination of local knowledge of the area and expert knowledge on the causes of eutrophication, determine as well as possible which are likely to be the principle causes of the problems in the water body of interest.

Various industries produce and use nitrogen and phosphorus containing products.

Sewage works can discharge effluents that can contribute significantly to nutrient loading. This source of nutrients was suggested as the primary cause of the problems experienced in the six most eutrophic impoundments in South Africa in 1975 [Toerien *et al.*, 1975]. Toerien et al. (1975) also noted nutrient enrichment in impoundments in areas of agricultural importance.

If non-point source runoff is thought to be the problem, choose downstream sampling sites that are most likely to be representative of the cumulative effects of the runoff. Difficulties can arise because runoff can be a diffuse source. However, if runoff from an area is ultimately concentrated into a single water course before entering the affected water body, this water course can be monitored.

In general, place sampling points upstream and downstream of the suspected sources at gauging stations (weirs).

If flows are measured at existing weirs in rivers flowing into the affected system, then sampling for the nutrients should be done at these points.

To be certain of the various relative contributions to the nutrient enrichment, a nutrient mass balancing exercise must be undertaken to ensure that ‘all bases have been covered’. Sites should be chosen with this in mind. In essence, the aim is to first establish the load (*e.g.* as kg/day) entering the impoundment of interest. Then, the total of the individual loads from suspected sources should be compared with the impoundment load (*i.e.* check the mass balance). If there is not a balance (within experimental error) then a significant source may have been omitted. Once a balance is obtained, the relative loads can also be used to distinguish between point and diffuse sources.

The incoming load can also be compared with the loads leaving the impoundment. This helps establish the extent to which the impoundment is acting as a ‘nutrient sink’. This can be an indication of its eutrophication activity if one assumes the retained N and P have been used by algae. However, such nutrients may be also accumulating in the sediment. If these are released back into the water body in future they can worsen the degree of nutrient enrichment and hence problems associated with eutrophication.

It should be noted that establishing a nutrient balance for an impoundment is not a trivial exercise. Careful thought must be given to all possible sources and destinations of nutrients, including those associated with groundwater and the plants themselves.

If the measurement of flow is not possible, then simply monitoring concentrations (as opposed to loads) upstream and downstream of potential nutrient sources can still be useful. Although a nutrient balance *per se* is not possible, such monitoring does give information about individual nutrient sources in isolation. It is not possible to quantitatively compare the relative contributions of different sources.

6.3.7.6 Sampling frequency

The pros and cons of a random versus regular monitoring frequency should also be considered. A regular monitoring frequency (*e.g.* every week on Monday) has the advantage of efficiency because a routine is established that other activities can revolve around and accommodate. However, if one purpose of the monitoring programme is to detect possible illegal activities, then a regular frequency is not necessarily appropriate. Those involved in the illegal activity may be able to adjust the timing of their activities to minimise the possibility of detection. In this case, it may be more appropriate to implement random sampling around a suitable average frequency.

A nutrient balance may require sampling over a period of one year so that the way the nutrient balance changes over that period can be monitored.

6.3.7.7 Quality control

QC Data quality objectives

To provide sufficiently accurate analyses and flow measurements at all the necessary points in and around the local water body so that a comprehensive nutrient balance is established.

QC Roles and responsibilities

The primary responsibility for local quality control lies with the local manager who should either personally perform the necessary tasks or allocate them to a suitably reliable and trained representative.

QC Data collection

At least 1 in every 20 samples taken (5%) should be split to produce a quality control sample. Analysis of this sample should be done by an accredited laboratory, or at least one that takes part in inter-laboratory studies that has been shown to be reliable.

QC Data evaluation

Since a nutrient balance is required, it is necessary that the total inputs and outputs of nutrients ‘balance’. This means that ‘what goes into the system, must either stay or leave the system’. An inadequate balance means that either some sources or destinations have not been detected or that the analyses or flows are inaccurate.

QC Systems and performance reviews

The Regional Monitoring Coordinator and/or the national coordinator should review all quality control data on a regular basis. Two aspects should be checked: First, all necessary quality control samples should have been analysed and their data captured. Secondly, the reviewer should check the data quality and quantity using the above data evaluation guidelines.

If insufficient quality control data have been determined, then all the data should be flagged as having ‘insufficient quality control’ in a way that this is clear to the person doing the ultimate data assessment.

If the analysis of the quality control data indicates poor quality data (*i.e.* they do not agree within reasonable experimental error), all data should again be flagged as having ‘insufficient quality control’.

If comparisons between analytical results and quality control results are satisfactory, the data should be flagged as ‘data reliability good’.

QC *Corrective actions*

If comparisons between analytical results and quality control results are unsatisfactory then corrective actions must be put in place to, first, determine the cause of the discrepancy and, secondly, ensure the discrepancy does not arise again.

The first action is to advise the agents responsible for sampling, analysis and data capture that a problem has been detected. Discussions with them may be sufficient to determine the cause of the problem.

If such discussions do not reveal the possible cause of the problem, personal visits to the sampling site (with the sampler) and/or the laboratory may be necessary. In each case, the procedures used should be carefully examined and recommendations made if necessary.

If sampling and laboratory techniques are deemed satisfactory, then discrepancies in the overall nutrient balance suggests that a source of destination has not been taken into account. All possible other sources and destinations need to be carefully considered and other sampling points introduced to detect them.

QC reports to management

The results of each regular quality control data evaluation exercise should be documented in a format that can be made available to any person who may perform any form of data assessment.

6.3.7.8 Data assessment and reporting

Data for individual variables can be compared with the South African water quality guidelines [DWAF 1996a-g] for the relevant water use.

More generally, the observed nutrient import and export rates should be assessed in the light of the catchment type, the hydromorphology and the capacity of the water body to process nutrients. The export rates should also be compared with the anticipated rates.

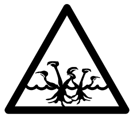
Reporting should be locally based initially, even for regional and national purposes. In other words, attempts should not be made to produce composite indices. Maps should be used to display the principle causes of nutrient enrichment for each impoundment for regional and national reporting.

6.3.7.9 Management

Resource quality objectives are not of direct relevance to establishing a nutrient balance for a particular water body. Of course, resource quality objectives could be defined for any of the nutrients but this is not related to the purpose of the current monitoring objective. The purpose is focussed on establishing and understanding the nutrient balance, at whatever levels the nutrients might be.

A framework for developing ‘single source interventions’ is available in a recent report [DWAF, 2000a]. This gives the requirements (actions and time-frames) for mitigating or remediating the water quality impacts from a single source, as part of a water use authorisation, a cooperative agreement or a directive. They will generally be applied to specific concerns that have a significant impact on the water quality of a water resource.

Table 6.5. Summary of monitoring variables and frequencies for local area objectives.

		Objective		Recommended	Useful
		Trophic status		TP, Chl *a* (**at least every 2 weeks**)	On site: Secchi Depth, EC, pH, Temp, DO. In laboratory: TN, TSS.
Early warning systems	Short term	**Water treatment**		**Every 2 weeks** phytoplankton counts and identification and visual monitoring. More frequent when problem encountered. **Monthly** in low risk water bodies.	More frequent visual monitoring of blooms *in situ* followed up by *ad hoc* laboratory analyses (if regular weekly phytoplankton counts not possible); cyanotoxins concentrations (if counts high); geosmin concentrations
		Algal blooms		**At least weekly (in high risk months) and monthly otherwise** visual monitoring *in situ*, and, if detected, counts and identification	More frequent visual monitoring *in situ*
		Invasive macrophytes		**At least monthly** visual monitoring *in situ*	More frequent visual monitoring *in situ*
	Long term	**Long term impacts**		**Annual** land use statistics, runoff factors and as for trophic status for validation	
		Nutrient balance		Flow, TP, TN, K (**at least every 2 weeks**)	

Recommended: Variables must always be included.
Useful: Variables that (1) may be omitted if limited by resource constraints or (2) that are important only under certain site-specific conditions.

7. PROCEDURE SPECIFICATIONS

This chapter should be used primarily by the Regional Monitoring Coordinator and the Local Manager for defining the procedures to be followed in a local monitoring programme.

CHAPTER CONTENTS

7.1 INTRODUCTION

It is important that monitoring procedures be as standardised as possible if comparable results are required for Water Management Areas and national objectives. If these methods are not adhered to, interpretation of the results may be seriously compromised.

The following sections provide a quality assurance plan and various recommended procedures. Which one should be used in any particular circumstance depends on the specific monitoring objective and available resources (see chapter Local Monitoring Frameworks). It is assumed in this chapter that the locations of sampling points have been determined. It should be noted that it is not absolutely necessary that the recommended procedures are adopted. However, it should be confirmed (with the regional manager or national coordinator) that any alternative method is appropriate. It should be a well-tested and standard method.

If anything is not understood, this manual should be consulted first. If the necessary information is not found, the regional manager should be consulted. Should the regional manager be unavailable (or not be able to provide the information), the national coordinator of the NEMP should be consulted.

7.2 QUALITY ASSURANCE PLAN

7.2.1 Introduction

Quality assurance is defined as follows: The implementation of all activities that minimise the possibility of quality problems occurring. One such activity is quality control. This is the process of ensuring that recommended monitoring procedures are followed correctly by detecting and correcting quality problems when they arise.

The general structure of this quality assurance plan is based on that of Shampine (1993). The primary purpose of the National Eutrophication Monitoring Programme is to collect, assess and report on the nature and extent of eutrophication and its associated problems on a national basis in South Africa. The design of the national programme is such that regional and local monitoring programmes are necessary (each with their own objectives). This section provides a basis for quality assurance at each of these levels.

Since site specific monitoring system designs are not given in this document, it is not appropriate to provide site specific quality assurance protocols. Each local (and hence regional and national) monitoring programme will need to have its own quality assurance plan developed at the time the detailed programme is designed. This section provides the basic framework upon which these should be based. Consistent with the general philosophy of this manual, this section provides recommendations which should be adapted to the specific requirements of each monitoring programme.

7.2.2 QA data quality objectives

The generic objective in respect of data quality (which includes data quantity, if appropriate) is that the defined objectives of the monitoring programme are achieved. This applies to the local, regional and national programmes.

7.2.3 QA roles and responsibilities

Responsibilities for quality assurance depend on whether the programme is local, regional or national. Typically, the National Coordinator is primarily responsible for national quality assurance. Regional Monitoring Coordinators are responsible for quality assurance within Water Management Areas (WMAs). Local Managers are usually responsible for quality assurance at individual impoundments, rivers or canals. Each is responsible for implementation of the various quality assurance activities and ultimately reporting (*i.e.* documenting) on their implementation including, specifically, quality control reports. Importantly, all should coordinate their activities as much as possible.

7.2.4 QA activities and data collection

Quality assurance activities include the following.

- Training to ensure correct sampling, sample preparation, sample preservation, sample analysis and data capture.
- Regular programmes of equipment servicing and calibration.
- Quality control.
- Regular regional and national feedback on improved procedures and how to avoid potential pitfalls.
- Appropriate implementation of a reward system for good sampling and analysis (*e.g.* based on the results of quality control investigations).

Some of these activities are described in detail in relevant parts of this manual. The exact details of others need to be decided at the time of implementation of local and regional programmes. It should also be noted that quality assurance activities should not be restricted to those mentioned above. As experience is gained in implementation of the NEMP, other activities are likely to be identified that address the primary aim of quality assurance, namely to minimise the possibility of quality problems occurring. These should be implemented as and when necessary.

The quality control aspect of quality assurance is defined for each local monitoring objective (see chapter Local Monitoring Frameworks). On an annual basis, Regional Monitoring Coordinators should collect quality control reports from each Local Manager and produce integrated quality control reports for each WMA. Similarly, the National Coordinator should collect the WMA quality control reports and produce another integrated report for South Africa as a whole.

7.2.5 QA data evaluation

The integrated quality control data at regional and national level should be evaluated to determine whether the respective monitoring objectives can be achieved.

7.2.6 QA systems and performance reviews

The assessment of the integrated quality control reports should be recorded so that general statements can be made regarding the data quality on a regional and national basis.

7.2.7 QA corrective actions

If the degree of quality control is deemed insufficient, the National Coordinator or the Regional Monitoring Coordinator should institute actions aimed at identifying the reasons for the inadequate quality and then correcting them. In the broader sense, these actions may include any quality assurance activity, not simply ensuring that recommended procedures are followed. For example, it may require the design of new training courses or changes to existing ones or updating of documentation.

7.2.8 QA reports to management

When monitoring reports are submitted, these must included explicit statements about the data quality.

7.3 ON-SITE MEASUREMENTS

7.3.1 Visual area estimation

The extent of the visible surface area of a water resource affected by an algal or cyanobacterial bloom or an invasive macrophyte should be estimated (and ultimately reported in hectares) using one of the following methods. The area above submerged infestations should be estimated as well as possible although the ability to do this is limited by the clarity of the water.

The person should be in a position that gives the best possible view of the whole infestation. For a small surface infestations (up to tens of square metres) or submerged infestations, this may need to be quite close, either on the water or the bank. For large infestations (hectares or km^2) of surface macrophytes then a high point is preferable, if available. This may be on the dam wall or even a nearby hilltop or hillside. In the case of macrophyte invasions, once a site is chosen, the same site should be used for future monitoring of that infestation.

The simplest mechanism for recording the degree of infestation is to mark it on an approximately A4-size map of the water body.

If the infestation can be expressed as a percentage of coverage of the whole water body, and the total area of the water body is known, then this method should be used to calculate the infestation coverage in hectares.

If the person doing the estimation is deemed competent to estimate the area directly in hectares (or any equivalent formal area unit, like m^2 or km^2) then this should be done.

If the person is visually unfamiliar with the hectare as an area unit, then that person should visually estimate the area in units of soccer fields. If a soccer field is assumed to be 100 m by 50 m (=0.5 hectares) this can be converted to an estimate in hectares, as follows.

$$\text{Area (hectares)} = 0.5 \text{x} N$$

where N = number of soccer fields.

7.3.2 Secchi disc depth

This method is based on the one used by DWAF.

7.3.2.1 Scope

A Secchi disc determines the clarity of water which in turn is inversely related to its turbidity.

7.3.2.2 Principle

The Secchi disc is lowered into the water until the black and white quadrants are just visible. This depth is a measure of the clarity of the water.

7.3.2.3 Apparatus

The metal Secchi disc is 20cm in diameter marked with alternative white and black quadrants. It is attached to a rope marked at 10 cm intervals. Alternatively, a measuring tape can be used if the rope is not marked.

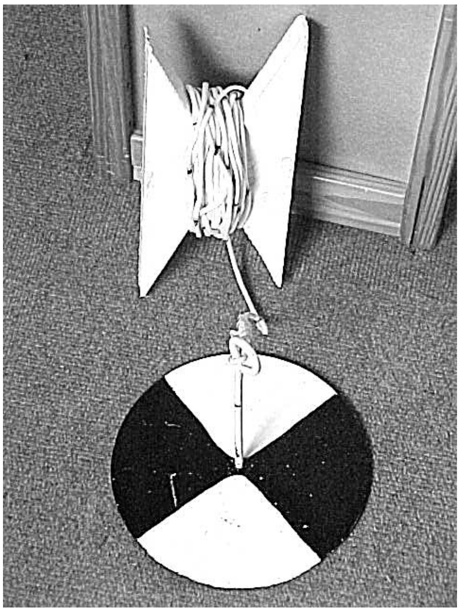


Figure 7.1. Secchi disk.

7.3.2.4 Procedure

- Lower the Secchi disc into the water, with the sun behind you, until it is out of sight. (If the sun is in front, reflections off the surface of the water can influence the visibility of the disc.)
- Lift the disc until it is just visible.
- Note and record the depth reading on the marked rope or using the measuring tape.

7.4 SAMPLING

7.4.1 5 m hosepipe samples

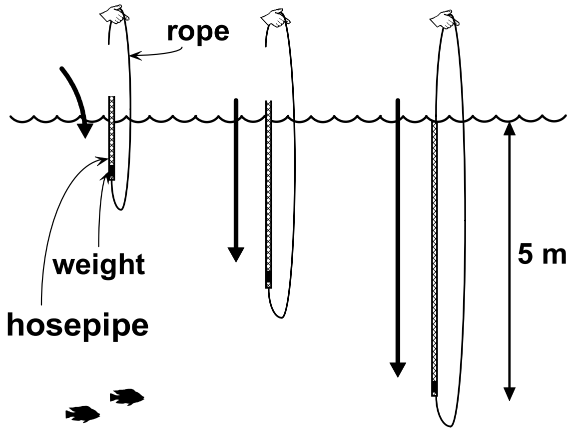
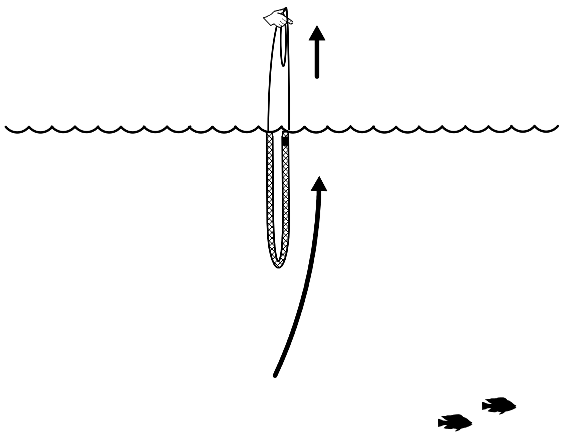
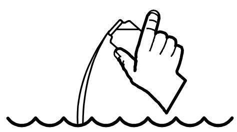
This method is based on the one used by DWAF [van Ginkel, 2001]. This form of sampling is recommended when an indication of the overall population (*i.e.* an integrated sample) is required. Sampling using this method is only appropriate when the depth at the sampling site is greater than 5 m.

7.4.1.1 Apparatus

★ 5m standard hosepipe (*e.g.* 15mm inner diameter), tied at both ends with a single piece of rope. If the sample is being taken from a boat, the rope can be 6 to 7 m long. If the sample will be taken from a point high above the water (like the dam wall) then the length of the rope must be at least the height of the wall above the water level plus 5 m. One end of the hosepipe is lead weighted. Store the hosepipe hanging or lying straight.

★ Clean plastic sample bottle with screw top (1 to 3 litres depending on algal density). Ensure the bottle is clean and clearly marked (preferably the day before used for sampling). If DWAF is to perform the analyses, then use the sample bottles supplied by DWAF.

7.4.1.2 Procedure

1	Slowly lower the weighted end of the hosepipe into the water so that it descends straight down (*i.e.* vertically) until the unweighted end is just below the surface. Ensure that the hosepipe is hanging in a vertical position. If sample is being taken from a boat, ensure that the boat is anchored.	 Lower vertically
2	Using the attached rope, pull up the weighted end (forming a U-shape) until that end reaches the surface. Raise the hosepipe out of the water, maintaining the U-shape.	 Raise in U-shape
3	Fill the sample bottle. Repeat steps 1 and 2 until sufficient sample has been collected. Ensure the correctly marked sample bottle is used.	 Fill sample bottle
4	Pour out a small amount (about 2 cm from the top of bottle). This allows the sample to be properly mixed before analysis.	 Decant 2 cm
5	Screw top tightly into place.	 Close tightly

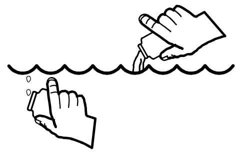
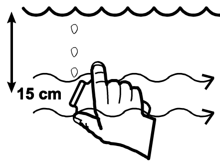
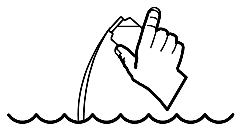
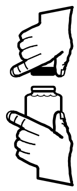
7.4.2 Subsurface grab samples

This method is based on the one used at Rand Water. Close access to the water is necessary, for example from a boat.

7.4.2.1 Apparatus

Clean plastic sample bottle with screw top (1 to 3 litres depending on algal density). Ensure the bottle is clean and clearly marked (laboratory name, date and sample name) preferably the day before used for sampling.

7.4.2.2 Procedure

1	Plunge the bottle in the water, fill with water and discard to rinse. Repeat this step. Ensure the correctly marked bottle is used.	 Rinse twice
2	Fill bottle again by holding the bottle about 15 cm below the surface.	 Take sample
3	Pour out a small amount (about 2 cm from the top of bottle). This allows the sample to be properly mixed before analysis.	 Decant 2 cm
4	Screw top tightly into place.	 Close tightly

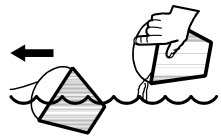
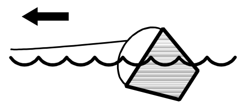
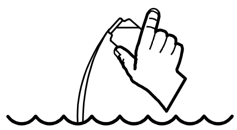
7.4.3 Surface grab samples

This method is based on the one used by DWAF. It should not be used when an obvious surface scum is present.

7.4.3.1 Apparatus

- ★ Clean plastic bucket. If the sample is to be taken from the bank, then a 3 m rope should be attached.
- ★ Clean plastic sample bottle with screw top (1 to 3 litres depending on algal density). Ensure the bottle is clean and clearly marked (laboratory name, date and sample name) preferably the day before used for sampling.

7.4.3.2 Procedure

1	Throw the bucket out into the water. Using the rope, haul in across the surface filling the bucket with water. Rinse and discard contents. Repeat this step.	 Rinse twice
2	Again throw the bucket out into the water and haul in collecting the sample.	 Take sample
3	Fill the sample bottle. Ensure the correctly marked sample bottle is used.	 Fill sample bottle
4	Pour out a small amount (about 2 cm from the top of bottle). This allows the sample to be properly mixed before analysis.	 Decant 2 cm
5	Screw top tightly into place.	 Close tightly

7.5 SAMPLE PREPARATION

These methods are based on those used by DWAF.

7.5.1 Chlorophyll *a*

★ Put the clean glass fibre filter paper between the top and bottom sections of the filter unit.
★ Carefully fill the top section of the filter unit up to the 250 mℓ mark with the sampled water.
★ Slowly create a vacuum, measuring up to 15 cm on the pressure gauge, so that water is slowly sucked through the filter paper.
★ Remove the receiver flask (bottom part of filter unit) and discard the water.
★ Replace the receiver flask.
★ If the water is not very turbid, again fill the top section to the 250 mℓ mark, remove the receiver flask and discard the water so that a total of 500 mℓ has been filtered. (If the water is very turbid, filtering more than 250 mℓ can take a long time.)
★ Carefully remove the top section of the filter unit and carefully remove the filter paper.
★ Roll this paper with the rough side (with the filtered substances) on the inside.
★ Place the rolled filter paper in the bottle containing the (colourless) ethanol.
★ Screw the bottle top tightly into place.
★ Write the time of sampling, the date, the sampling site (*e.g.* the dam name) and the volume filtered on the label on the bottle.

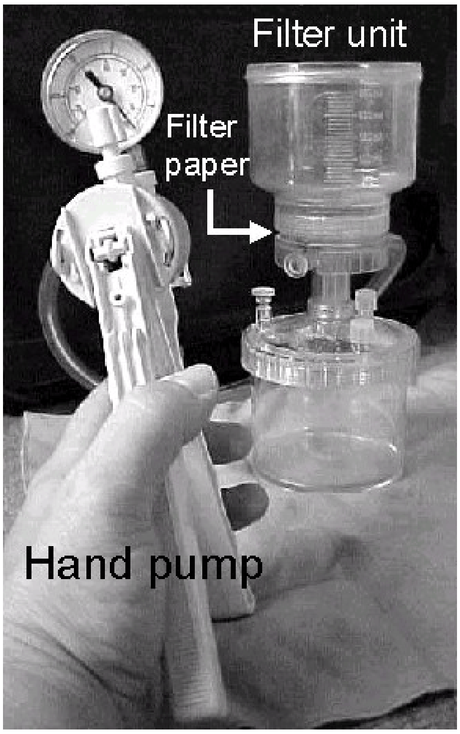


Figure 7.2. Portable hand filter apparatus.

7.6 SAMPLE PRESERVATION

These methods are based on those used by DWAF.

Table 7.1. Recommended sample preservatives.

Variable	Recommended preservative
Chlorophyll *a*	Ethanol (as extractant and preservative)
Phytoplankton counts	Lugol's solution
Phytoplankton identification	Lugol's solution
Total phosphorus	$HgCl_2$ to give 6 mg/ℓ Hg(II)
Total nitrogen	$HgCl_2$ to give 6 mg/ℓ Hg(II)
Kjeldahl nitrogen	$HgCl_2$ to give 6 mg/ℓ Hg(II)
Nitrate	$HgCl_2$ to give 6 mg/ℓ Hg(II)
Nitrite	$HgCl_2$ to give 6 mg/ℓ Hg(II)
pH	Not necessary
Electrical conductivity	Not necessary
Total Suspended Solids	Not necessary

7.7 LABORATORY OR *IN SITU* ANALYSIS

7.7.1 Analytical procedures

This section states the general type of analytical method to be used for each variable. Most are based on those used at DWAF which in turn are based on recognised Standard Methods (1995 or more recent). The exceptions are the phytoplankton procedures which are based on those used at Rand Water. If detailed procedures are required, these should be obtained from DWAF.

Table 7.2. Recommended analytical procedures.

Variable	Recommended procedure	Reporting units
Chlorophyll *a*	Spectrophotometry	μg/ℓ
Phytoplankton counts	Sedimentation and enumeration using an inverted microscope	cells/mℓ
Phytoplankton identification	As at Rand Water (using an inverted microscope)	
Total phosphorus	Phosphomolybdate colorimetry	mg/ℓ
Total nitrogen	Kjeldahl nitrogen + nitrate + nitrite	mg/ℓ
Kjeldahl nitrogen	Digestion and colorimetry	mg/ℓ
Nitrate	Cadmium reduction	mg/ℓ
Nitrite	Colorimetry	mg/ℓ
pH	pH electrode	pH
Electrical conductivity	Conductivity meter	mS/m
Total Suspended Solids	Filtration	mg/ℓ

7.7.2 Quality assurance

Use should preferably be made of accredited laboratories. If this is not possible, then laboratories that take part in inter-laboratory studies and that are known to be (or can be shown to be) reliable should be chosen.

Standard laboratory quality assurance and quality control procedures must be in place within the laboratory. The laboratory should be able to provide details of such procedures on request.

8. ROLES AND RESPONSIBILITIES

This chapter should be used by any role player to establish the tasks required to be implemented by any of the role players in the NEMP.

CHAPTER CONTENTS

8.1 OVERALL INFORMATION FLOW

A multitude of parties are involved in a national monitoring programme. All individual roles need to be smoothly executed for the overall programme to be successful. This chapter describes each individual role and their responsibilities, though fairly generically. The actual flow of data and information within the overall scheme is shown in the figure.

The roles cover the whole range from sampler to national policy maker. This has been done to ensure that each role player understands where they fit into the overall picture. This should facilitate buy-in to the process and hence contribute to sustainability of the programme.

The exact tasks associated with each local role will depend on the specific local monitoring objective and associated monitoring design. Of primary importance on deciding on the detailed tasks is that they all focus primarily on the chosen monitoring objective(s) (whether local, regional or national). An important factor is also that many of the local monitoring designs have local as well as regional and national objectives. It is extremely important to remember that local monitoring programmes are in place so that a ‘win-win’ situation is achieved in which both local and regional/national objectives are met.

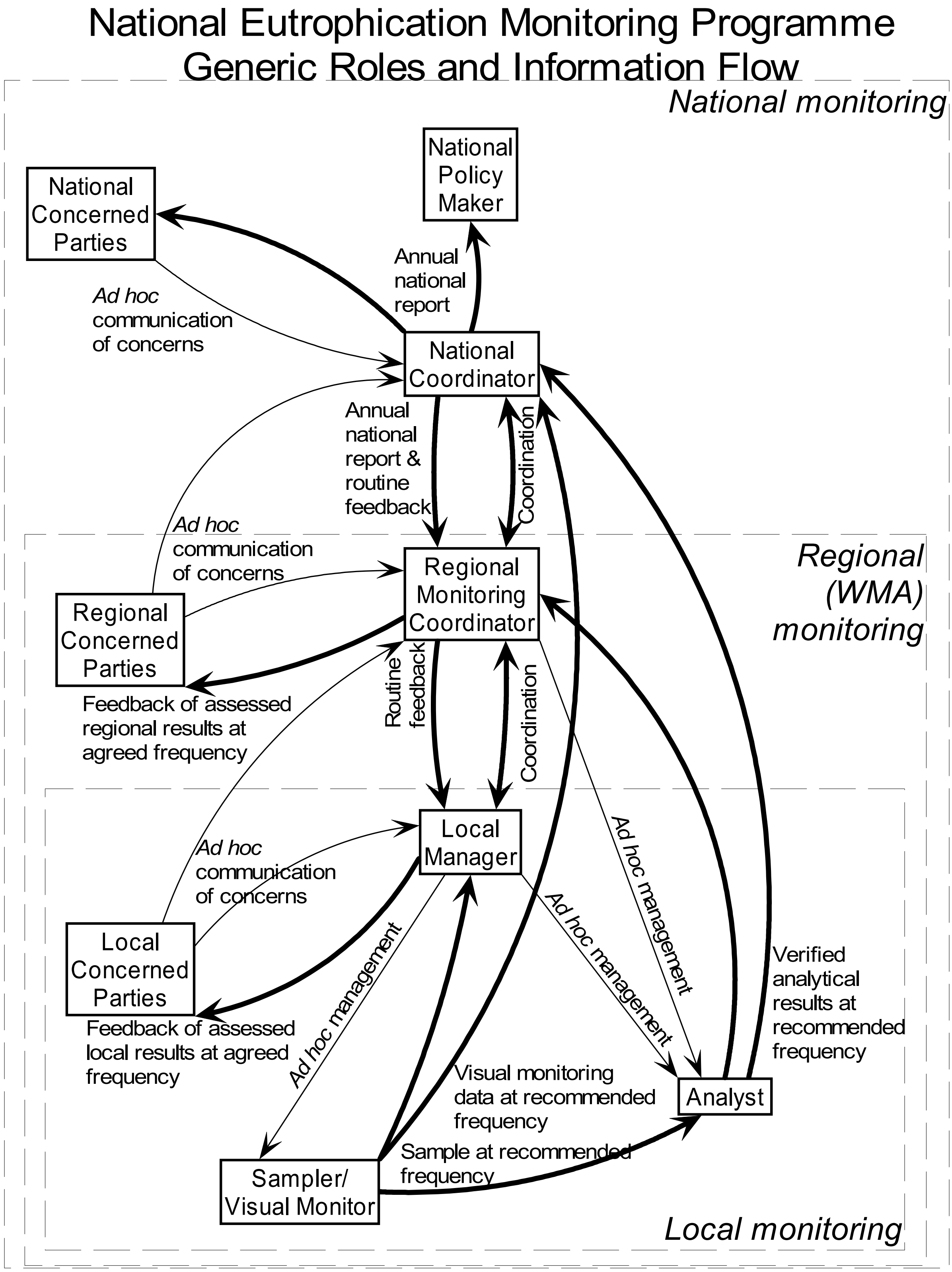
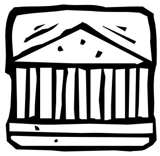


Figure 8.1. Generic NEMP monitoring roles.

8.2 NATIONAL POLICY MAKER



8.2.1 Summary of Role

The **National Policy Maker** receives annual reports from the **National Coordinator**. These are reports that are the information products that address directly the national objectives of the NEMP (see section NATIONAL OBJECTIVES in chapter NATIONAL IMPLEMENTATION). It is the responsibility of the **National Policy Maker** to use this information to implement current policy and develop new policy for the national management of surface water resources.

8.2.2 Typical Role Player

Minister of Water Affairs and Forestry, Water Affairs management committee.

8.2.3 Tasks

A Minister is generally responsible for the powers and functions assigned to him/her by the President. As a Member of Cabinet, he or she is accountable to Parliament for the exercise of these powers and the performance of their functions. A Member of Cabinet must (a) act in accordance with the constitution and (b) provide Parliament with full and regular reports concerning matters under their control.

The following extract from the Water Act summarises in general terms the ultimate responsibility of the Minister of Water Affairs and Forestry.

Sustainability and equity are identified as central guiding principles in the protection, use, development, conservation, management and control of water resources. These guiding principles recognise the basic human needs of present and future generations, the need to protect water resources, the need to share some water resources with other countries, the need to promote social and economic development through the use of water and the need to establish suitable institutions in order to achieve the purpose of the Act. National Government, acting through the Minister, is responsible for the achievement of these fundamental principles in accordance with the Constitutional mandate for water reform. Being empowered to act on behalf of the nation, the Minister has the ultimate responsibility to fulfil certain obligations relating to the use, allocation and protection of and access to water resources.

8.3 NATIONAL COORDINATOR

8.3.1 Summary of Role

The primary role is to facilitate, coordinate and manage the nationwide implementation of the national eutrophication monitoring programme so that the national objectives are achieved. The **National Coordinator** will typically represent DWAF in negotiations with regional and local parties, ensuring that the minimum requirements are in place to meet the national objectives. The **National Coordinator** will need to be familiar with all aspects of eutrophication monitoring and should be able to provide technical and managerial advice to role players at all levels. The **National Coordinator** must ensure effective and efficient transfer of knowledge and experience gained by those involved in the programme.

8.3.2 Typical Role Player

A person from the Department of Water Affairs and Forestry (DWAF).

8.3.3 Tasks

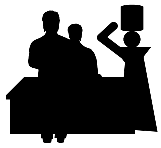
8.3.3.2 Facilitate National Implementation

The **National Coordinator** should be the driving force behind initial and ongoing implementation on a national basis. This will involve choosing appropriate areas for initial implementation. See section National Implementation Process in the chapter National Implementation. A wide variety of issues must be also explicitly considered (see section Implementation Issues in chapter National Implementation).

8.3.3.3 Facilitate Regional and Local Implementation

With the experienced gained from implementation in other local areas, the **National Coordinator** should facilitate the implementation of monitoring programmes in new areas. Details are given in the chapters Regional Implementation and Local Implementation.

8.4 NATIONAL CONCERNED PARTIES



8.4.1 Summary of Role

The **National Concerned Parties** receive the same annual reports from the **National Coordinator** that are sent to the **National Policy Maker**. It is their responsibility to communicate concerns and comments to the **National Coordinator**.

8.4.2 Typical Role Player

Any person or organisation with an interest in the national status of eutrophication and its associated problems. These include the Department of Water Affairs and Forestry (the formal national custodian of the programme), the Department of Agriculture and the Department of Environment Affairs and Tourism.

8.4.3 Tasks

Government departments should use the NEMP information products to contribute constructively to strategic national decisions.

Non-governmental **National Concerned Parties** must communicate their concerns and comments to the **National Coordinator**. It is the responsibility of the **National Concerned Parties** to become involved in the national implementation of the NEMP to the extent necessary to ensure that the NEMP continues to produce information products that are appropriately focussed on their needs.

8.5 REGIONAL MONITORING COORDINATOR

8.5.1 Summary of Role

The **Regional Monitoring Coordinator** has responsibilities assigned by DWAF in respect of management and coordination in a particular Water Management Area (WMA). The primary role of the **Regional Monitoring Coordinator** is to initialise local monitoring programmes, ensure their sustainability and ensure the regional monitoring data are forwarded to the **National Coordinator**.

8.5.2 Typical Role Player

Department of Water Affairs and Forestry (DWAF) or CMA representative.

8.5.3 Tasks

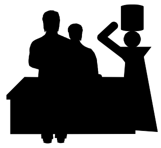
8.5.3.1 Initialisation of new monitoring programmes

The **Regional Monitoring Coordinator** must collaborate closely with the **National Coordinator** to establish new local monitoring programmes. See chapters Regional Implementation and Local Implementation for more details.

8.5.3.2 Ensure sustainability

To ensure sustainability of local programmes, the **Regional Monitoring Coordinator** must address a number of issues. See chapters Regional Implementation and Local Implementation for more details.

8.6 REGIONAL CONCERNED PARTIES



8.6.1 Summary of Role

Regional Concerned Parties receive regular reports which serve as information products for their own regional (*i.e.* Water Management Area) interests. They can communicate concerns and comments to either the **Regional Monitoring Coordinator** or the **National Coordinator**.

8.6.2 Typical Role Player

Water Quality Managers of Department of Water Affairs and Forestry (DWAF) Regional Offices, Catchment Management Agencies (CMAs) or any other regional organisation that regards itself as a stakeholder in the use of water resources in their Water Management Area.

8.6.3 Tasks

Regional Concerned Parties should communicate concerns and comments to either the **Regional Monitoring Coordinator** or the **National Coordinator**. It is the responsibility of the **Regional Concerned Parties** to become involved in the regional implementation of the NEMP to the extent necessary to ensure that the regional monitoring programmes continue to produce information products that are appropriately focussed on their needs.

8.7 LOCAL MANAGER

8.7.1 Summary of Role

The **Local Manager** is typically a member of a local stakeholder organisation which has become involved in the NEMP primarily for their own purposes. The **Local Manager**, therefore, has that local organisation's interests as the highest priority. Local day-to-day management will therefore be primarily at the discretion of that **Local Manager**. However, involvement in the NEMP also means that regional and national interests must also be taken into account. The exact responsibilities of the **Local Manager** are defined in the contract negotiated between that person and DWAF. The **Local Manager** must therefore ensure that the agreed data are transmitted to the **Regional Monitoring Coordinator** and/or **National Coordinator** for inclusion in the national database.

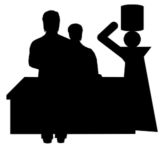
8.7.2 Typical Role Player

Any organisation that regards itself as a stakeholder in the use of a local water body.

8.7.3 Tasks

The **Local Manager**, in collaboration with the **Regional Monitoring Coordinator**, will initialise, manage and sustain a local monitoring programme. See chapter Local Implementation for more details.

8.8 LOCAL CONCERNED PARTIES



8.8.1 Summary of Role

Local Concerned Parties receive regular reports which serve as information products for their own local interests. They can communicate concerns and comments to either the **Local Manager** or **Regional Monitoring Coordinator**.

8.8.2 Typical Role Player

Any organisation that regards itself as a stakeholder in the eutrophication-related water quality of a local water body.

8.8.3 Tasks

Local Concerned Parties should communicate concerns and comments to either the **Local Manager** or **Regional Monitoring Coordinator**. It is the responsibility of the **Local Concerned Parties** to become involved in the regional implementation of the NEMP to the extent necessary to ensure that the local monitoring programmes continue to produce information products that are appropriately focussed on their needs.

8.9 ANALYST

8.9.1 Summary of Role

The **Analyst** receives samples from the **Sampler/Visual Monitor**. The samples should be analysed for the necessary variables as soon as possible. The results must be stored locally and transmitted to the **Regional Monitoring Coordinator** and/or **National Coordinator** for inclusion in the national database.

8.9.2 Typical Role Player

Accredited laboratory.

8.9.3 Tasks

8.9.3.1 Sample Preservation

Before and after analysis, samples must be stored in a cool room.

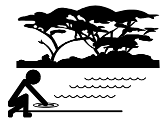
8.9.3.2 Sample Analysis

Samples must be analysed using the agreed analytical method. Appropriate laboratory quality assurance and quality control procedures must be adhered to. See chapter Procedure Specifications for more details.

8.9.3.3 Results transmission

Results must be transmitted to the **National Coordinator** for direct inclusion in the national database. Use should preferably be made of spreadsheets for this purpose.

8.10 SAMPLER



8.10.1 Summary of Role

The **Sampler** physically travels to the designated sampling sites at the agreed frequency (weekly, fortnightly, ...), takes the samples, prepares and preserves them following recommended procedures, marks the containers with the date and sample site identification and delivers the sample containers to the **Analyst**. **Samplers** should also routinely complete and submit the 'On site visual monitoring report sheet' (see appendix).

8.10.2 Typical Role Player

Accredited laboratory, DWAF officers, water board or local authority.

8.10.3 Tasks

8.10.3.1 Preparation

Before departing for the sampling site, all the necessary equipment should be checked and it should be ensured that report sheets are at hand.

8.10.3.2 On site

The recommended procedures specifications (or the agreed alternatives) should be followed closely. See chapter Procedure Specifications for more details. The necessary samples should be collected, prepared and preserve according to specifications and sample containers labelled.

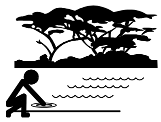
The 'On site visual monitoring report sheet' should be completed.

8.10.3.3 Delivery

Samples should be delivered (or posted, as agreed) to the assigned laboratory as soon as possible.

Copies of the report sheets should be made and kept locally before sending the report sheets to the **Local Manager**, **Regional Monitoring Coordinator** or **National Coordinator**.

8.11 VISUAL MONITOR



8.11.1 Summary of Role

The **Visual Monitor** physically travels to the designated monitoring sites at the agreed frequency (weekly, fortnightly, ...) and makes various visual observations. In the case of a bloom being observed, the **Visual Monitor** takes the necessary samples, prepares and preserves them following recommended procedures, marks the containers with the date and sample site identification and delivers (or posts) the sample containers to the **Analyst**. The **Visual Monitor** should routinely complete and submit the 'On site visual monitoring report sheet'.

8.11.2 Typical Role Player

Sampler, accredited laboratory, DWAF officers, water board or local authority.

8.11.3 Tasks

8.11.3.1 Preparation

Before departing for the sampling site, all the necessary sampling equipment should be checked and visual identification aids and report sheets ensured at hand.

8.11.3.2 On site

The recommended visual monitoring procedures(or the agreed alternatives) should be followed closely. Samples should be collected if an algal, diatom or cyanobacterial bloom is detected, prepared and preserved and sample containers labelled. See chapter Procedure Specifications for details.

The 'On site visual monitoring report sheet' (see appendix) should be completed.

8.11.3.3 Delivery

The samples should be delivered (or posted, as agreed) to the assigned laboratory as soon as possible.

Copies of the report sheets should be made and kept locally before sending the report sheets to the **Local Manager**, **Regional Monitoring Coordinator** or **National Coordinator**.

9. THE BUSINESS OF MONITORING

This chapter should be used by the National Coordinator and the Regional Monitoring Coordinator for guidance on some of the general business principles relevant to successful implementation of the NEMP.

CHAPTER CONTENTS

9.1 INTRODUCTION

Setting up and sustaining a national monitoring system is very much like running a business. There is a product (an 'information product') consisting of the monitoring data and assessments and a need (of management) which must be satisfied. Marketing of the product is required. There is income required for the costs of implementation. There is the classic 'bottom-line'. It also operates in a competitive environment (competing, for example, against other national priorities for funding). In business parlance, the NEMP is a 'service cost centre' (in essence, a cost to DWAF that provides a service to it).

This chapter describes some monitoring implementation issues from a more formal business point of view. It does not attempt to be comprehensive. Some issues, like costing, are dealt with in some detail. Others are summarised very briefly simply to make the reader aware of certain ways of thinking that should facilitate a more effective implementation of the NEMP.

9.2 POTENTIAL FUNDING SOURCES

9.2.1 Generic model

Although implementation of the NEMP is primarily the responsibility of DWAF, there are various other potential resource providers. The primary point of departure, however, is that DWAF will be responsible for NEMP-related monitoring at least to the minimum requirements defined for meeting the national objectives. When catchment management agencies (CMAs) become established, they could become responsible for costs in their respective water management areas. Appropriate coordination and negotiation between the CMAs, DWAF and local agents (contracted by the CMAs) should enable objectives at each level to be achieved simultaneously.

When CMAs become established and water charges invoked that cover their expenses (of which monitoring is but one), then the NEMP could become less dependent on resource contributions made directly from DWAF. The following figure illustrates this schematically. This figure is deliberately non-quantitative and does not commit either DWAF nor any other resource provider to anything. It merely illustrates a likely trend.

Relative contributions of resource providers

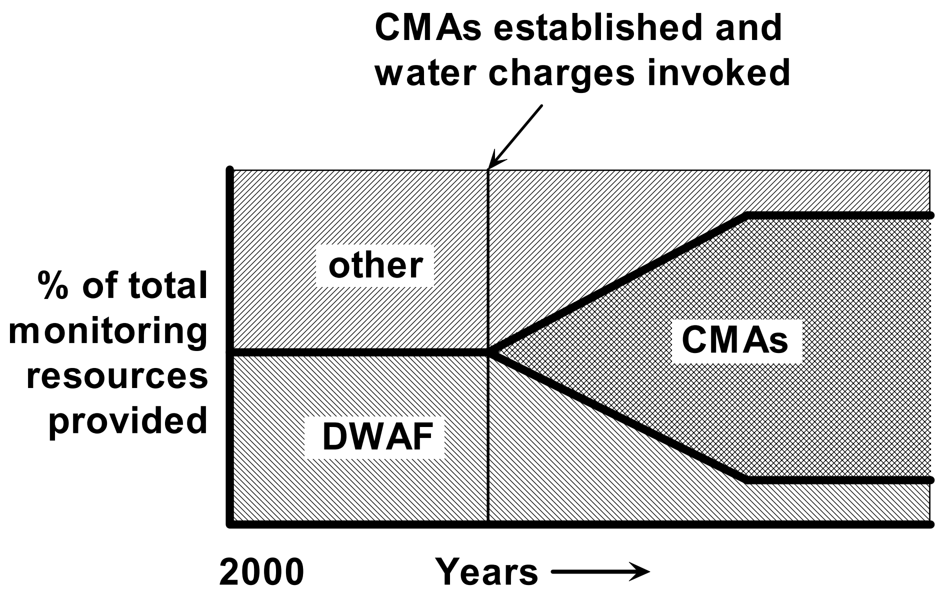


Figure 9.1. Schematic illustration of the likely future trends in the relative contributions of resource providers.

9.2.2 International resources

International resources are only likely to be applicable when significant initial capital costs are envisaged. International donors are very unlikely to fund operating costs.

If this route is taken, it must be realised that mobilising international donor sources is itself expensive, time consuming and requires specialist knowledge and experience.

In the context of a national programme such as the NEMP, it will be very important that proposals to international donors be well coordinated. To ensure this, all such proposals should be approved (preferably produced) by the National Coordinator.

9.2.3 National resources

These potentially include the following.

- DWAF
- DEAT (since potentially contributing to SoE reporting)

9.2.4 Regional resources

Resources for monitoring in water management areas could come from the two principle resources, namely, regional DWAF offices and CMAs (see **Figure 9.1**).

9.2.5 Local resources

Local resources could potentially come from any person or organisation who has an interest in a local water resource. They could either be involved in management of the resource or simply use it. These could include water management institutions, water suppliers, industry, educational institutions and recreational organisations (boating, fishing etc.).

9.3 A MODEL FOR IMPLEMENTATION COSTING

9.3.1 Background

The degree to which the various current and future stakeholders are prepared to commit resources to the implementation of the NEMP is an important factor determining its ultimate success. Monitoring on the national scale envisaged here is expensive. It should also not be expected of any stakeholder (including DWAF) to make resources available to the NEMP without having included such allocations in their previous annual budget cycle.

This section describes, and applies, an implementation costing model that can be used for budgeting purposes on a local, regional and national scale.

An implementation costing tool for monitoring programmes was developed for the National Microbial Monitoring Programme. It was developed sufficiently generally to be applicable to eutrophication monitoring as well. It exists in the form of two Microsoft Excel spreadsheets:

CostOne.xls	Single local implementation costing model
CostMany.xls	Regional or National implementation costing model

It is intended that DWAF will be the primary user of this facility though DWAF will use it in collaboration with other resource providers.

9.3.2 Costing model instructions

9.3.2.1 Costing a single local programme

A local area is defined as one comprised of a series of sampling sites from which samples are collected at regular intervals (the sampling frequency) and typically associated with a single impoundment or river reach. Each of the sites is assumed visited in one 'round' of sampling.

Costs can be specified for each of a number of roles. These roles include sampling, analysis, initial capacity building, database management, coordination (initial and ongoing) and others.

Each role comprises a series of items (or tasks). For example, analysis may comprise the measurement of a series of variables (like chlorophyll *a* or pH), each with their own associated cost. Initial capacity building might comprise the subsistence and travel costs for a visit to the local area (by the National Coordinator, for example) and training costs.

The model (*i.e.* spreadsheet CostOne.xls) is based on annual costs. It allows the user to specify annual operating costs, human resource costs (hourly rates and hours) and capital costs (and associated lifetimes) for each of the items for each of the specified roles.

Importantly, it allows distinction between up to four 'resource providers'. So costs can be shared between different resource providers and be transparently shown to be so. For example, a series of resource providers might include DWAF head office, a DWAF regional office and a local non-DWAF source like a water board. In future the DWAF regional office will be replaced by a CMA.

The interface is intended to be relatively simple and self-evident. However, instructions are included to guide the user in the overall use of the model. The local area model can be used jointly with each resource provider in the area.

For any specific area, the file 'CostOne.xls' should be copied to a file with a name indicating the local area, *e.g.* 'Botshabelo.xls'.

The user starts by specifying such information as the names of up to four resource providers and an annual percentage escalation in costs being assumed. The specific costs for individual items can then be specified in separate worksheets, each associated with a different role.

Having specified all individual costs for the first year, five-year projected annual implementation costs are automatically created. Separate projections (in separate worksheets) exist for each resource provider and one exists for all combined. In each projection the total costs are broken down into operating costs, human resource costs and capital and depreciation costs. Human resource hours are also shown. Each such projection (worksheet) can be printed on a single A4 page.

The advantages of the facility are as follows.

- ❑ The resource providers can jointly optimise parameters (such as the number of sampling sites and the variables to be analysed) to ensure that total costs are within reasonable limits.
- ❑ Costs incurred by all resource providers can be distinguished so all are aware of what the others are contributing, creating total transparency.
- ❑ Since human resource hours are also recorded, each resource provider knows what time commitments are necessary.

9.3.2.2 Costing regional or national implementation

A region in this context is simply regarded as a number of local programmes. The costs for an ‘average local programme’ are defined in the file ‘CostOne.xls’ (as though it was referring to a real local area). These costs are multiplied by the number of local programmes specified by the user.

There are some tasks that are assumed to exist in regional and national planning that do not occur for local programmes (so-called ‘region-specific’ and ‘national-specific’ costs). For example, there will be a degree of ‘generic national coordination’ that is independent of the number of local programmes currently active (for example, the production of a newsletter). There may also be an annual assessment of data from all local programmes aimed at producing an integrated picture of the region or nation. (This cost would typically be a function of the number of local programmes.) As for the local area model, costs can be specified for individual tasks for these various operations. These are added to the costs of the active local programmes.

In summary, the total regional costs comprised of N local area programmes (that have all started in the same year) can be specified as follows:

Total regional costs = Nx(average local area costs) + (region-specific costs)

Similarly, total national costs comprised of M local area programmes can be specified as follows:

Total national costs = Mx(average local area costs) + (national-specific costs)

Regional parameters are specified in the model in file ‘CostMany.xls’. The user can specify an increasing (cumulative) number of such average local programmes in each of the five years. For example, it may be required that the number of local programmes increase by five each year for five years. The number of local programmes would then be 5, 10, 15, 20, and 25 respectively for the five years.

The regional model CostMany.xls obtains the average local area costs directly from the file CostOne.xls.

As for the local area model, five-year projected costs are automatically created with a detailed breakdown of contributing costs. Each can also be printed on an A4 page.

9.3.2.3 Model assumptions

The following are some of the simple assumptions upon which the calculations are based.

- ❑ A constant cost escalation factor (specified by the user as a percentage) exists over the five projection period.
- ❑ In the regional and national model, local programmes that start in the second and subsequent years have initial costs that include the cost escalation factor.
- ❑ Capital expenditure only occurs in the first year (in which a local programme starts).
- ❑ Depreciation costs start in the second year. A linear depreciation model calculates these costs as (initial capital cost)/lifetime, where lifetime is specified by the user in years. (The capital item is assumed to have zero value at the end of its lifetime.)

It is important that when these models are used for actual budgeting purposes that these assumptions and all the detail encapsulated in the individual spreadsheets be examined and checked carefully for accuracy and appropriateness.

9.3.3 Predominant costs for a local programme

It has been stated [Sanders *et al.*, 1987] that professional judgement and cost constraints often provide the basis for sampling frequencies (as opposed to formal scientific analysis). In order to obtain a local (South African) perspective on costs, the implementation costing model was used to get a feeling for what aspect of monitoring is the most expensive. No attempt was made to provide highly accurate figures. Only 'ball-park' figures were used. This rough modelling was done prior to the detailed design of the overall monitoring system to avoid unnecessarily complex analyses and designs that would in any case be overridden in practice by resource constraints. That is, the purpose of this preliminary costing analysis was *specifically to influence the ultimate monitoring programme design*, at least by focussing attention on the most costly aspects of national monitoring.

Accordingly, the following assumptions were made.

Costs for a single typical 'average local area' were chosen. Various combinations of two-weekly and weekly sampling at either 5 or 10 sampling sites were examined with two analytical costs per sample, namely R100 and R1000. The overall implementation process involved an initial capacity building phase, initial coordination (visits to the area and sampling sites) and a degree of on-going coordination. Reporting was assumed to be in the form of two-monthly feedback reports to the 'Area Monitor' who was responsible for day-to-day management of the local programme. A small amount of national database management was also included. No capital costs were included.

The results of the model appear in the adjacent tables.

Table 9.2. Effect of sampling frequency and number of sites on total annual costs assuming an analytical cost of R100 per sample.

Frequency: every two weeks Number of sites: 5								
Hours		**Oper Costs**		**HR Costs**		**Total**		
126.1		**R 42 810**		**R 17 560**		**R 60 370**		
0	0%	R 26 000	61%	R 0	0%	R 26 000	43%	Sampling
0.1	0%	R 13 000	30%	R 1 300	7%	R 14 300	24%	Analytical
16	13%	R 1 000	2%	R 2 080	12%	R 3 080	5%	Initial capacity building
3	2%	R 0	0%	R 270	2%	R 270	0%	National Database Management
1	1%	R 10	0%	R 130	1%	R 140	0%	Bi-monthly assessment and reporting
40	32%	R 500	1%	R 5 200	30%	R 5 700	9%	Area monitoring
34	27%	R 1 300	3%	R 4 420	25%	R 5 720	9%	Initial National Coordination
32	25%	R 1 000	2%	R 4 160	24%	R 5 160	9%	On-going National Coordination
Frequency: every two weeks Number of sites: 10								
Hours		**Oper Costs**		**HR Costs**		**Total**		
126.1		**R 55 810**		**R 18 860**		**R 74 670**		
0	0%	R 26 000	47%	R 0	0%	R 26 000	35%	Sampling
0.1	0%	R 26 000	47%	R 2 600	14%	R 28 600	38%	Analytical
16	13%	R 1 000	2%	R 2 080	11%	R 3 080	4%	Initial capacity building
3	2%	R 0	0%	R 270	1%	R 270	0%	National Database Management
1	1%	R 10	0%	R 130	1%	R 140	0%	Bi-monthly assessment and reporting
40	32%	R 500	1%	R 5 200	28%	R 5 700	8%	Area monitoring
34	27%	R 1 300	2%	R 4 420	23%	R 5 720	8%	Initial National Coordination
32	25%	R 1 000	2%	R 4 160	22%	R 5 160	7%	On-going National Coordination
Frequency: weekly Number of sites: 5								
Hours		**Oper Costs**		**HR Costs**		**Total**		
126.1		**R 81 810**		**R 18 860**		**R 100 670**		
0	0%	R 52 000	64%	R 0	0%	R 52 000	52%	Sampling
0.1	0%	R 26 000	32%	R 2 600	14%	R 28 600	28%	Analytical
16	13%	R 1 000	1%	R 2 080	11%	R 3 080	3%	Initial capacity building
3	2%	R 0	0%	R 270	1%	R 270	0%	National Database Management
1	1%	R 10	0%	R 130	1%	R 140	0%	Bi-monthly assessment and reporting
40	32%	R 500	1%	R 5 200	28%	R 5 700	6%	Area monitoring
34	27%	R 1 300	2%	R 4 420	23%	R 5 720	6%	Initial National Coordination
32	25%	R 1 000	1%	R 4 160	22%	R 5 160	5%	On-going National Coordination

Table 9.3. Effect of sampling frequency and number of sites on total annual costs assuming an analytical cost of R1000 per sample.

Frequency: every two weeks Number of sites: 5								
Hours		**Oper Costs**		**HR Costs**		**Total**		
126.1		**R 159 810**		**R 17 560**		**R 177 370**		
0	0%	R 26 000	16%	R 0	0%	R 26 000	15%	Sampling
0.1	0%	R 130 000	81%	R 1 300	7%	R 131 300	74%	Analytical
16	13%	R 1 000	1%	R 2 080	12%	R 3 080	2%	Initial capacity building
3	2%	R 0	0%	R 270	2%	R 270	0%	National Database Management
1	1%	R 10	0%	R 130	1%	R 140	0%	Bi-monthly assessment and reporting
40	32%	R 500	0%	R 5 200	30%	R 5 700	3%	Area monitoring
34	27%	R 1 300	1%	R 4 420	25%	R 5 720	3%	Initial National Coordination
32	25%	R 1 000	1%	R 4 160	24%	R 5 160	3%	On-going National Coordination
Frequency: every two weeks Number of sites: 10								
Hours		**Oper Costs**		**HR Costs**		**Total**		
126.1		**R 289 810**		**R 18 860**		**R 308 670**		
0	0%	R 26 000	9%	R 0	0%	R 26 000	8%	Sampling
0.1	0%	R 260 000	90%	R 2 600	14%	R 262 600	85%	Analytical
16	13%	R 1 000	0%	R 2 080	11%	R 3 080	1%	Initial capacity building
3	2%	R 0	0%	R 270	1%	R 270	0%	National Database Management
1	1%	R 10	0%	R 130	1%	R 140	0%	Bi-monthly assessment and reporting
40	32%	R 500	0%	R 5 200	28%	R 5 700	2%	Area monitoring
34	27%	R 1 300	0%	R 4 420	23%	R 5 720	2%	Initial National Coordination
32	25%	R 1 000	0%	R 4 160	22%	R 5 160	2%	On-going National Coordination
Frequency: weekly Number of sites: 5								
Hours		**Oper Costs**		**HR Costs**		**Total**		
126.1		**R 315 810**		**R 18 860**		**R 334 670**		
0	0%	R 52 000	16%	R 0	0%	R 52 000	16%	Sampling
0.1	0%	R 260 000	82%	R 2 600	14%	R 262 600	78%	Analytical
16	13%	R 1 000	0%	R 2 080	11%	R 3 080	1%	Initial capacity building
3	2%	R 0	0%	R 270	1%	R 270	0%	National Database Management
1	1%	R 10	0%	R 130	1%	R 140	0%	Bi-monthly assessment and reporting
40	32%	R 500	0%	R 5 200	28%	R 5 700	2%	Area monitoring
34	27%	R 1 300	0%	R 4 420	23%	R 5 720	2%	Initial National Coordination
32	25%	R 1 000	0%	R 4 160	22%	R 5 160	2%	On-going National Coordination

These results give a clear message. Sampling and analytical costs combined are the predominant contributors to the overall costs. Also, these costs are primarily operating costs (not human resource costs). At relatively low analytical costs (R100/sample), sampling costs predominate. At high analytical costs (R1000/sample), analytical costs predominate.

The conclusion of this preliminary costing analysis is that (from a financial point of view only) serious consideration should be given to **optimising the number of sampling sites and having sampling as infrequent as possible** (without significant loss if information). Note that sampling costs are usually more a function of sampling frequency (not the number of sites). Analytical costs are a function of both sampling frequency and the number of sites (since they depend on the number of samples analysed).

The sampling costs can be significantly minimised if sampling rounds are planned to coincide with other existing monitoring programmes, so that costs can be shared with those programmes. This kind of ‘consolidation’ (or avoidance of duplication) is a fundamental issue that is addressed by the Water Management System at DWAF. Full use should be made of this.

9.4 CREATING AND SUSTAINING COMMITMENT

9.4.1 The importance of sound sampling and analysis

The implementation of a national programme such as the one being designed in this report should not be expected to ‘simply happen’. It will require a degree of buy-in at all levels within DWAF and in other organisations involved whether formal contracts exist or not. At higher levels it will require a ‘champion’ who will coordinate and enthusiastically manage and drive the programme as a whole. However, enthusiasm at this level only will not be sufficient. The success of the monitoring programme requires commitment by many people at lower levels in the structure. This is particularly so for the many people who do the actual visual monitoring and reporting and/or collecting of samples and submission of these to the appropriate laboratories. This section focusses on these people, referred to here as ‘samplers’.

These samplers may already be DWAF employees or may be employed by some non-DWAF organisation to perform the sampling. Samplers may also be members of the public who take it upon themselves to report visual sightings of algal blooms or macrophyte invasions.

For sake of clarity, the following are defined as the tasks of a ‘sampler’ (of which the sampler may do one or more). These tasks may appear in formal contracts or DWAF job descriptions.

- ❑ Regularly (say once every week or month) **look for visual evidence** of algal blooms and macrophyte invasions **and report** on the presence or absence of (1) blooms, (2) specific macrophytes (identified using a handbook or brochure) and (3) an estimate of area affected by the bloom or macrophyte.
- ❑ When a phytoplankton bloom is observed, **take water samples** using a precisely specified procedure (*e.g.* using a 5 m hosepipe), **preserve the sample** in a

specified way **and ensure delivery** of the sample so that it reaches a designated laboratory as soon as possible.

Although some degree of initial training is likely to be necessary, these tasks are, by their very nature, routine. The tasks requiring some aptitude are the macrophyte identifications and the estimate of area. However, it should be possible to simplify the latter task by training the sampler to think in terms of commonly understood units of area, such as the area of a soccer field.

The routine nature of the tasks will not inspire interest or commitment. The sampler gains little out of doing the work. Actual management of the water resource is not likely to be the samplers responsibility. So the sampling tasks will be seen as simply another burden with no direct gain. It is assumed here that simply having the sampling tasks as part of their job descriptions will not suffice. That is, simply being told by their immediate superiors that they should perform the tasks is insufficient.

The reality is that the sampler's tasks are critical to the overall success of the national, Water Management Area and local programmes. If their tasks are not performed at the required frequency, or not with recommended procedures, the quality of the data being received (if received at all) can be compromised to the extent that achieving the ultimate objectives is impossible.

Therefore, it is proposed that the implementation of a reward system should be seriously considered. Indeed, it should be regarded as a factor crucial to the successful implementation of the NEMP.

9.4.2 Reward systems in general

This section gives some generic background on the concept of reward systems.

In general, people tend to maximise rewards and reduce costs in social situations [Morgan and King, 1971]. ***Rewards*** are events that bring gratification. They result in material gain, enhanced self-esteem, bring social approval and so on. ***Costs*** are events that result in loss of material things or that lower self-esteem, increase tension and anxiety and so on. An individual consciously or unconsciously weighs the various alternatives in a situation and decides what he/she will do. The individual tries to anticipate which course of action will be the most rewarding with the least cost. Specifically, people seek to maximise rewards and minimise costs (seek pleasure and avoid pain) in the present and they plan actions to bring rewards and minimise costs in the future.

A reward system should align the actions and objectives of individuals with the objectives and needs of the overall strategy [Pearce and Robinson, 1991].

Financial incentives are important reward mechanisms. They are particularly useful when directly linked to specific activities and results.

Intrinsic (non-financial) rewards such as flexibility and autonomy in a job are important managerial motivators.

Negative sanctions, such as withholding of financial and intrinsic rewards are necessary ingredients in encouraging the manager's efforts.

The time horizon on which rewards and sanctions are based is a major consideration in linking them to strategically important activities and results. Short-term rewards structures can result in actions and decisions that undermine long-term aims. Short-term incentive schemes typically focus on the last year's performance. This has the following weaknesses.

- It is backward looking.
- The focus is short-term.
- Strategic gains or losses are not considered.

Nevertheless, short-term incentive schemes are important. However, short- and long-term concerns must be integrated and reward systems based on the assessment of both short-term and long-term (strategic) considerations. Ideally, an effective rewards system should provide payoffs that control and evaluate the creation of potential future performance as well as last year's results. For example, review and evaluation in a specific year must include both an assessment of performance during the past year and progress towards a defined, say five-year, strategic objective.

Ball and Asbury (1990) in 'The Winning Way' noted that top South African companies ***measure what they want to happen and reward people when it does.*** Both motivation and reward are regarded as key elements in the implementation of strategy. One aspect of this is the tailoring of personal goals to corporate objectives. Whether there are formal performance measurements systems that are linked into the strategic process or not, super-performing companies all use informal reward systems. 'Strategic behaviour' is rewarded with awards, citations, certificates and plaudits. Informal does not mean *ad hoc*. These programmes should be carefully thought out so that the right behaviour is publicly recognised and encouraged.

One of the best ways to build or reinforce a culture is to publicly recognise exemplary behaviour.

9.4.3 Rewards and national monitoring

9.4.3.1 Introduction

The primary objective of a rewards system for samplers in a national monitoring programme is to encourage a commitment to all aspects of the recommended monitoring and sampling protocols. This can be done in two basic ways. First, the perceived status of samplers can be raised from the outset. Secondly, rewards for jobs well done can be provided.

9.4.3.2 Increased status

Rewards that increase the sampler's status can include a variety of possibilities.

- When the sampler is first approached, the importance of sampling especially from a local community point of view can be emphasised.
- A name can be used for samplers that reflects their importance. The zulu word 'Umlindi' (meaning the watchman) is a good one but is already used in the Agricultural Geographical Information System (AGIS). Other words meaning 'lifeguard' or 'the protector' are also possible.
- Local communities can be made aware of who is protecting them and their water resources (give the sampler a card with his photograph on it and a description of what he does).
- Certificates for attendance at courses.

9.4.3.3 Rewards for commitment

Sampling methods can only be assessed by a formal quality control exercise in which the sampler is observed taking the samples in the prescribed way. The accuracy of visual monitoring can only be assessed by an appropriate expert confirming the initial identification. The frequency can be established by the number of samples analysed or reports received of visual monitoring results.

The first task is to define appropriate measures of what is required for the monitoring programmes to be successful. The following table contains some possibilities. In a monitoring context, there is little difference between a one-year and five-year time frame from the sampler's point of view. The suggestions are therefore assumed applicable to either.

The choice of reward and to whom it is made and why must be very carefully considered. The perceptions and sensitivities of the people receiving the reward (and not receiving one) should be considered.

Particular attention should be paid to people and organisations that involve themselves in the NEMP 'beyond the call of duty'. That is, particularly outstanding achievements should receive special rewards or simply compliments (and thanks).

Table 9.4. Measures of degree of successful sampling.

Objective	Measures of successful sampling
Trophic status	Percentage of total possible number of samples actually analysed
Water treatment (reasons: avoid taste & odour & filter clogging problems)	as for trophic status
Algal blooms (reasons: avoid scums, odours, health risks due to direct use of raw water)	1. Percentage of total possible number of reports submitted on presence/absence of blooms (necessary for national and WMA perspective on nature and extent of the problem) 2. Blooms actually reported in time (*i.e.* sufficiently early) for water managers to invoke appropriate management actions (necessary for 'early warning system')
Invasive macrophytes (reasons: minimise water loss, ecological & recreational impacts)	as for blooms
Long term impacts (reasons: avoid all eutrophication related impacts)	as for trophic status
Nutrient balance	as for trophic status

The following actual rewards can be considered.

- When a cyanobacterial bloom is detected and successfully managed (*i.e.* locals warned in time), the local community can be informed of who alerted the authorities and saved them from exposure to the polluted water.

- 'Sampler of the Year' award, involving one or more of the following:

  Financial bonus (say 5% of annual salary).

  Signed and framed photograph of Minister of Water Affairs thanking Sampler of the Year for his/her commitment to duty.

  Framed certificate.

  Publicity in the national newsletter.

9.5 MARKETING

Different marketing approaches will need to be adopted (by the National Coordinator and/or Regional Manager). These will depend on the particular type of monitoring programme objective and on the nature of the prospective resource provider. Various marketing tools are provided in this document (such as the various diagrams). The use of these need to be tailored to the specific target audience.

A professional marketing person or organisation should be employed to develop an appropriate marketing strategy and implement specific marketing drives. What is to be marketed must be clearly defined and everything should be in place within the parameters of the marketing campaign. It is important that it is never necessary to say ".. but this is coming in future."

9.6 PUBLIC RELATIONS

9.6.1 Introduction

Public relations management has become increasingly important in public and private organisations in South Africa [Lubbe and Puth, 1994]. Continuing with the assumption that a national monitoring programme can be regarded in many ways as a business, it is evident that public relations is an aspect that should be carefully considered and managed. The following is largely based on the above reference.

9.6.2 Basic principles

This section summarises some basic principles which will serve to focus the reader on certain aspects which are likely to be relevant to the NEMP.

For any particular organisation, public relations can be defined as follows.

Public relations is the management function that identifies, establishes and maintains mutually beneficial relationships between an organisation and the various publics on whom its success or failure depends.

In the context of the NEMP, the "publics" include those individuals and organisations involved in any role from sampling, analysis (like laboratories), data assessment, reporting, and so on, through to those managers who will use the monitoring data.

The NEMP will be managed by DWAF and many of the "publics" just identified may also be within DWAF. Conceptually, it is better to regard the "organisation" (in the public relations definition) to be that programme within DWAF responsible for its management. The word "publics" could also be replaced with the phrase "involved parties". Accordingly, the following slightly modified definition is given.

*Public relations **in the NEMP** is the management function that identifies, establishes and maintains mutually beneficial relationships between **the DWAF NEMP programme** and the various **involved parties** on whom its success or failure depends.*

The "DWAF NEMP programme" is assumed to comprise the National Coordinator, immediate superiors and support staff and functions.

Public relations and marketing are two functions that are often confused. Public relations is typically incorporated into the larger, more powerful marketing function.

The way public relations departments in an organisation can be organised gives some insights into the kinds of the focus that are possible.

- Structure by involved party.

- Structure by management process (planning, communication, research etc.)
- Structure by communication technique.
- Structure by geographic region.
- Structure by organisational subsystem.

Lubbe and Puth (1994) note that the organisation which has the greatest potential for on-going success in the exchange of values with its environment (the involved and interested parties), is one that <u>interacts actively</u> with its environment for the mutual benefit of both organisation and environment. This could be interpreted as meaning that <u>the National Coordinator must actively engage all involved and interested parties</u> to ensure success of the NEMP.

Communication is a dynamic, two-way process through which meaning is shared between two or more people. Like communication, public relations is viewed as a two-way process and is, by its very nature, communication in action. ***Public relations communicates and does so persuasively.***

Communication can have specific aims. It may be to establish mutual understanding or it may be to inform, persuade or influence attitudes in order to bring about action.

Corporate leaders are realising that each of an organisations publics must be dealt with in different ways. Lines of communication will differ. Each is important in its own way so that priorities cannot be set by allowing one public to take precedence over another.

A "public" is seen to be any group which has some involvement with an organisation. The identification of different publics is analogous to the marketing principle of dividing the market into different segments. An internal public consists of staff of the organisation itself, including management.

Corporate image serves as a launch-pad for marketing activities. ***Corporate image*** *is defined as the net result of interaction of all experience, impressions, beliefs, feelings and knowledge people have about a company*. Two important factors that determine successful corporate image are (1) coordination of communication activities and (2) consistency of all company advertising. Everything a company does or doesn't do adds to or detracts from its image.

Consistency of all advertising includes such aspects as the use of a logo in all communications as well as the use of consistent NEMP letterheads in written correspondence.

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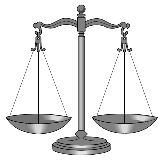

Appendix A: Water Act Chapter 14

(For the complete Act, see http://www.acts.co.za/ntl_water/index.htm)

CHAPTER 14

MONITORING, ASSESSMENT AND INFORMATION

Monitoring, recording, assessing and disseminating information on water resources is critically important for achieving the objects of the Act. Part 1 of this Chapter places a duty on the Minister, as soon as it is practicable to do so, to establish national monitoring systems. The purpose of the systems will be to facilitate the continued and co-ordinated monitoring of various aspects of water resources by collecting relevant information and data, through established procedures and mechanisms, from a variety of sources including organs of state, water management institutions and water users.

Part 1: National monitoring systems

Establishment of national monitoring systems

137. (1) The Minister must establish national monitoring systems on water resources as soon as reasonably practicable.
(2) The systems must provide for the collection of appropriate data and information necessary to assess, among other matters -
(a) the quantity of water in the various water resources;
(b) the quality of water resources;
(c) the use of water resources;
(d) the rehabilitation of water resources;
(e) compliance with resource quality objectives;
(f) the health of aquatic ecosystems; and
(g) atmospheric conditions which may influence water resources.

Establishment of mechanisms to co-ordinate monitoring of water resources

138. The Minister must, after consultation with relevant -
(a) organs of state;
(b) water management institutions; and
(c) existing and potential users of water, establish mechanisms and procedures to co-ordinate the monitoring of water resources.

Part 2: National information systems on water resources

Part 2 requires the Minister, as soon as it is practicable to do so, to establish national information systems, each covering a different aspect of water resources, such as a national register of water use authorisations, or an information system on the quantity and quality of all water resources. The Minister may require any person to provide the Department with information prescribed by the Minister in regulations. In addition to its use by the Department and water management institutions, and subject to any limitations imposed by law, information in the national systems should be generally accessible for use by water users and the general public.

Establishment of national information systems

139. (1) The Minister must, as soon as reasonably practicable, establish national information systems regarding water resources.
(2) The information systems may include, among others -
(a) a hydrological information system;
(b) a water resource quality information system;
(c) a groundwater information system; and
(d) a register of water use authorisations.

Objectives of national information systems

140. The objectives of national information systems are -
(a) to store and provide data and information for the protection, sustainable use and

management of water resources;
(b) to provide information for the development and implementation of the national water resource strategy; and
(c) to provide information to water management institutions, water users and the public -
(i) for research and development;
(ii) for planning and environment impact assessments;
(iii) for public safety and disaster management; and
(iv) on the status of water resources.

Provision of information

141. The Minister may require in writing that any person must, within a reasonable given time or on a regular basis, provide the Department with any data, information, documents, samples or materials reasonably required for -
(a) the purposes of any national monitoring network or national information system; or
(b) the management and protection of water resources.

Access to information

142. Information contained in any national information system established in terms of this Chapter must be made available by the Minister, subject to any limitations imposed by law, and the payment of a reasonable charge determined by the Minister.

Regulations for monitoring, assessment and information

143. The Minister may make regulations prescribing -
(a) guidelines, procedures, standards and methods for monitoring; and
(b) the nature, type, time period and format of data to be submitted in terms of this Chapter.

Part 3: Information on floodlines, floods and droughts

Part 3 requires certain information relating to floods, droughts and potential risks to be made available to the public. Township layout plans must indicate a specific floodline. Water management institutions must use the most appropriate means to inform the public about anticipated floods, droughts or risks posed by water quality, the failure of any dam or any other waterworks or any other related matter. The Minister may establish early warning systems to anticipate such events.

Floodlines on plans for establishment of townships

144. For the purposes of ensuring that all persons who might be affected have access to information regarding potential flood hazards, no person may establish a township unless the layout plan shows, in a form acceptable to the local authority concerned, lines indicating the maximum level likely to be reached by floodwaters on average once in every 100 years.

Duty to make information available to public

145. (1) A water management institution must, at its own expense, make information at its disposal available to the public in an appropriate manner, in respect of -
(a) a flood which has occurred or which is likely to occur;
(b) a drought which has occurred or which is likely to occur;
(c) a waterwork which might fail or has failed, if the failure might endanger life or property;
(d) any risk posed by any dam;
(e) levels likely to be reached by floodwaters from time to time;
(f) any risk posed by the quality of any water to life, health or property; and
(g) any matter connected with water or water resources, which the public needs to know.
(2) The Minister may, where reasonably practicable, establish an early warning system in relation to the events contemplated in subsection (1).

Appendix B: Form Templates

NEMP

Monitoring Design Summary

for the local objective to establish trophic status

Impoundment name: ....

Number of sampling sites: ....

Sampling procedure

Recommended:
☐5m hosepipe

If not, specify procedure to be used, with reasons
☐...
....

Analytical variables

Recommended:
☐Total phosphorus
☐Chlorophyll *a*

Useful:
☐Secchi Depth
☐Electrical conductivity
☐Total nitrogen
☐Total Suspended Solids
☐pH
☐Temperature
☐Dissolved oxygen

Other:
☐
☐
☐
☐
☐

Analytical methods

Recommended:
☐As in manual

If not, specify variables and methods to be used, with reasons
☐...
☐...
☐...
☐...

Sampling frequency

Recommended:
☐Two-weekly

If not, specify frequency, with reasons
☐...
....

Quality control

Recommended:
☐As in manual

If not, specify QC methods, with reasons
☐...
....
....

National Coordinator: NEMP | DATE | Local Manager

NEMP
Monitoring Design Summary
for the local objective to establish a nutrient balance

Impoundment/river/canal name: ....

Number of sampling sites: ....

Sampling procedure

Recommended: ☐sub-surface

If not, specify procedure to be used, with reasons
☐...
....

Analytical variables

Recommended:	*Useful:*	*Other:*
☐Total phosphorus	☐Electrical conductivity	☐
☐Total nitrogen	☐Total Suspended Solids	☐
☐Potassium	☐pH	☐

Analytical methods

Recommended: ☐As in manual

If not, specify variables and methods to be used, with reasons
☐...
☐...
☐...
☐...

Sampling frequency

Recommended: ☐Two-weekly

If not, specify frequency, with reasons
☐...
....

Quality control

Recommended: ☐As in manual

If not, specify QC methods, with reasons
☐...
....
....

________________	________________	________________
National Coordinator: NEMP	DATE	Local Manager

NEMP

Monitoring Design Summary

for the local objective to establish a long term early warning system for long term impacts

Impoundment name: ....

Number of sampling sites: ....

Sampling procedure

Recommended: ☐5m hosepipe

If not, specify procedure to be used, with reasons
☐...
....

Analytical variables

Recommended:
☐Total phosphorus
☐Chlorophyll *a*

Useful:
☐Secchi Depth
☐Electrical conductivity
☐Total nitrogen
☐Total Suspended Solids
☐pH
☐Temperature
☐Dissolved oxygen

Other:
☐
☐
☐
☐
☐

Analytical methods

Recommended: ☐As in manual

If not, specify variables and methods to be used, with reasons
☐...
☐...
☐...
☐...

Sampling frequency

Recommended: ☐Two-weekly

If not, specify frequency, with reasons
☐...
....

Quality control

Recommended: ☐As in manual

If not, specify QC methods, with reasons
☐...
....
....

National Coordinator: NEMP	DATE	Local Manager

NEMP

Monitoring Design Summary

for the local objective to establish a short term early warning system for water treatment

Impoundment/river/canal name: ....

Number of sampling sites: ....

Sampling procedure

Recommended: *If not, specify procedure to be used, with reasons*

☐sub-surface ☐…………………………………………………………………………

…………………………………………………………………………..

Analytical variables

Recommended: *Other:*

☐Phytoplankton counts ☐

☐Phytoplankton identification ☐

Analytical methods

Recommended: *If not, specify variables and methods to be used, with reasons*

☐As in manual ☐……………………………………………………………………

☐……………………………………………………………………..

☐……………………………………………………………………

☐……………………………………………………………………..

Sampling frequency

Recommended: *If not, specify frequency, with reasons*

☐Weekly ☐…………………………………………………………………………

…………………………………………………………………………..

Visual monitoring

Recommended: *If not, specify frequency, with reasons*

☐Weekly ☐…………………………………………………………………………

…………………………………………………………………………..

Quality control

Recommended: *If not, specify QC methods, with reasons*

☐As in manual ☐…………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………….

National Coordinator: NEMP DATE Local Manager

NEMP

Monitoring Design Summary

for the local objective to establish a short term early warning system for algal blooms

Impoundment/river/canal name: ....

Visual monitoring

Recommended: *If not, specify frequency, with reasons*

☐Weekly ☐..
....

And, when detected visually, ...

Sampling procedure

Recommended: *If not, specify procedure to be used, with reasons*

☐5 m hosepipe ☐..
....

Analytical variables

Recommended: *Other:*

☐Phytoplankton counts ☐

☐Phytoplankton identification ☐

Analytical methods

Recommended: *If not, specify variables and methods to be used, with reasons*

☐As in manual ☐..

☐..

☐..

☐..

Sampling frequency

Recommended: *If not, specify frequency, with reasons*

☐Weekly ☐..
....

Quality control

Recommended: *If not, specify QC methods, with reasons*

☐As in manual ☐..
....
....

National Coordinator: NEMP	DATE	Local Manager

NEMP

Monitoring Design Summary

for the local objective to establish a short term early warning system for invasive macrophytes

Impoundment/river/canal name: ....

Visual monitoring frequency

Recommended: *If not, specify frequency, with reasons*

☐As in manual ☐……………………………………………………………………………
……………………………………………………………………………………
…………………………………………………………………………..

Quality control

Recommended: *If not, specify QC methods, with reasons*

☐As in manual ☐……………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………

National Coordinator: NEMP | DATE | Local Manager

Institute for Water Quality Studies
Department of Water Affairs and Forestry
Private Bag X313
Pretoria 0001
Tel: (012) 808 0374
Fax: (012) 808 2702

NEMP
On site visual monitoring report sheet

Impoundment/river/canal name: ....
Impoundment number: .... Date: .... Time: ....

Observations potentially related to eutrophication

Observation	Response	Reported by (name and contact no.)*:
Algal growth causing water discolouration?	Yes ☐ No ☐ If yes: Floating ☐ Submerged ☐ Scums ☐	
Problematic macrophyte growth?	Yes ☐ No ☐ If yes, estimated area covered: hectares (100m x 100m) = or, % of dam surface covered = or, number of soccer fields (100m x 50m) =	
Recent fish kills?	Yes ☐ No ☐ If yes, where?	
Recent animal deaths possibly related to the water?	Yes ☐ No ☐ If yes, where?	
Recent water taste or odour problems?	Yes ☐ No ☐ If yes, where? At impoundment ☐ Treatment works ☐ End user ☐ Other:………………………………	

* if reported to you though not observed directly by you.

Local conditions and measurements

Wind speed	Very strong ☐ Strong ☐ Mild ☐ Calm ☐
Direction from which wind blowing (N, S, E, W, NE, ...)	
Wind direction with respect to impoundment wall	☐ ☐ ☐
Gauge plate reading (m)	
Secchi Depth (m)	

Additional comments:

Equipment required?

Sampler name

Sampler signature