National Aquatic Ecosystem Biomonitoring Programme

Overview of the design process and guidelines for implementation

NAEBP Report Series No 6

Department of Water Affairs and Forestry

Department of Environmental Affairs and Tourism

Water Research Commission

Published by the

Department of Water Affairs and Forestry

April 1997

All enquiries should be addressed to:

The Director: Institute for Water Quality Studies
Private Bag X313
PRETORIA 0001
Republic of South Africa

Tel: (012) 808-0374

This report should be cited as:

Roux, D.J. 1997. National Aquatic Ecosystem Biomonitoring Programme: Overview of the design process and guidelines for implementation. NAEBP Report Series No 6. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

Compiled by:

Dirk Roux
Division of Water, Environment and Forestry Technology
CSIR
PRETORIA
South Africa

National Biomonitoring Programme for Riverine Ecosystems

Overview of the design process and guidelines for implementation

Table of Contents

Acknowledgements

The contributions of the following groups and individuals are gratefully acknowledged:

- **The Project Team:** Dr Henk van Vliet, Dr Neels Kleynhans and Ms Liesl Hill (Institute for Water Quality Studies); Dr Jane Harris and Mr Derek Hohls (Environmentek, CSIR); Dr Jackie King, Ms Cate Brown and Mr Sean Eekhout (Southern Waters Research and Consulting); Prof Jay O'Keeffe, Dr Patsy Goetsch and Ms Mandy Uys (Institute for Water Research); Ms Tisha Greyling, Ms Qondi Vilakazi and Ms Vanessa Daniel (Greyling Liaison); Dr Steve Mitchell (Water Research Commission); Mr Geoff Cowan (Department of Environmental Affairs and Forestry).

- **Participants of the Consultation Planning Meeting:** This meeting took place on 17 September 1996 at the CSIR Conference Centre, Pretoria.

- **Reviewers of this report:**

Dr Henk van Vliet	Institute for Water Quality Studies
Dr Steve Mitchell	Water Research Commission
Mr Geoff Cowan	Department of Water Affairs and Forestry
Dr Jane Harris	Environmentek, CSIR
Mr Derek Hohls	Environmentek, CSIR
Dr Neels Kleynhans	Institute for Water Quality Studies
Ms Tisha Greyling	Greyling Liaison
Dr Jenny Day	Freshwater Research Unit, UCT
Dr Jackie King	Southern Waters Research and Consulting
Prof Jay O'Keeffe	Institute for Water Research
Dr Chris Dickens	Umgeni Water

Executive Summary

Background

The limited nature of freshwater in South Africa, makes these resources critically important in terms of sustainable economic and social development. The Department of Water Affairs and Forestry (DWAF) has the responsibility of managing the country's water resources. The DWAF must, therefore, ensure that water bodies retain their ecological qualities, in order to remain fit to provide in the basic needs of humans as well as to support economic growth.

Effective decision-taking and resource management depend, however, on the information provided by effective resource monitoring. For many years the DWAF has relied on the monitoring of those physical and chemical stressors which are presumed to have an effect on the health of aquatic ecosystems. However, the worldwide trend is to, in addition to physical and chemical monitoring, adopt direct measurements of ecosystem health. Such direct measurements of environmental effects usually provide more reliable and integrated results of the overall condition of ecological resources.

Indicators of ecological integrity

Ecosystem health can be viewed as a value judgement of the overall condition of an ecosystem, based on the social well-being, economic development and ecological integrity within that system. To find a balance that will sustain ecosystem health, management decisions rely upon the availability of appropriate and adequate data on each of the above ecosystem components. Data on ecological integrity can be collected by monitoring key ecological indicators.

Ecological indicators can be divided into biological indicators (e.g. fish or invertebrate community characteristics) and non-biological (e.g. habitat characteristics) indicators. Each of these indicators can be used to measure and quantify ecological changes in an ecosystem.

Biological monitoring

The in-stream biological condition of a river ecosystem is determined by a multitude of factors, including its geomorphological characteristics, hydrological and hydraulic regimes, chemical and physical water quality and nature of the riparian vegetation. Aquatic communities integrate and reflect the effects of all these and other chemical and physical impacts occurring over extended periods of time. These communities are, therefore, regarded as good indicators of overall ecological integrity. Aquatic biomonitoring refers to the gathering of information on these biological indicators for the purpose of making some sort of environmental assessment.

When designing a biomonitoring programme, attention should be given to aquatic community components that are representative of the larger ecosystem and are practical to measure. The taxonomic groups may also vary depending on the type of aquatic ecosystem being assessed. For example, benthic macro-invertebrates and fish are often used as taxonomic groups to assess flowing waters, while plants are used in wetlands and algae and zooplankton in lakes and estuaries. The design of a biomonitoring programme should be tailored for the particular type of water-bodies assessed (e.g. wetland, lake, stream, river or estuary).

Biomonitoring programme for South Africa

To address the need for information on the state of aquatic ecosystems in South Africa, the DWAF has launched an initiative to develop a programme for monitoring the health of aquatic ecosystems. This programme is known as the National Aquatic Ecosystem Biomonitoring Programme (NAEBP).

Several approaches to the design and implementation of biomonitoring programmes have been followed around the world. The programme being designed for South Africa will incorporate appropriate concepts and components from existing international models, yet be tailored to reflect the unique environmental conditions and resource realities of this country.

Phasing of the programme design

A phased approach was adopted for the design of the NAEBP, to facilitate the formulation of a design framework, the conceptual development, testing and demonstration and eventual full-scale implementation of the programme.

Framework design for the NAEBP

The framework design is influenced mainly by two factors, namely the information required from the programme and the technical and practical feasibility of delivering that information. As the NAEBP is being designed primarily as a management information system, a survey of information requirements was conducted among water resource managers. These information needs ranged from determining the state and associated trend of ecosystems (at a national level) to identifying impacts, setting quality objectives and providing data for predictive modelling (at provincial, catchment-based and local levels).

It is unlikely that one biomonitoring programme will meet all information needs. As the NAEBP is required to provide information on a national level, its design must be specified accordingly. As such, it was decided that the focus of the NAEBP would primarily be on the ecological state of aquatic ecosystems.

Objectives of the NAEBP

The main objectives of the NAEBP are to:

- measure, assess and **report on the ecological state** of aquatic ecosystems,
- **detect** and report on spatial and temporal **trends** in the ecological state of aquatic ecosystems, and
- **identify** and report on emerging **problems** regarding the ecological state of aquatic ecosystems in South Africa.

Benchmarks for health assessment

Water resource managers will benefit from the knowledge that an ecosystem is responding in some way that is outside its natural range of variation. Therefore, when interpreting biomonitoring results, an attempt should be made to distinguish between natural and unnatural ranges of variation. One way of doing this is to establish a natural baseline (or reference condition) which can be used for evaluating monitoring results. Once appropriate reference conditions have been set for a particular region, standardised indices for measuring ecological integrity can be used and the resulting data can be compared against these regional reference conditions.

Conceptual design for the NAEBP

The conceptual design provides protocols for some of the technical components of the monitoring programme. The development of these conceptual specifications was guided by the objectives and the framework design of the programme. It was also assumed that the output from the NAEBP would primarily be used for either State-of-the-Environment (SOE) reporting or for impact assessment.

The technical specifications developed during the conceptual design include a protocol for the selection of sampling sites and protocols for selecting ecological indicators.

Protocol for selecting sampling sites

The NAEBP is being designed to allow comparison between reference and monitoring sites, where:

- **Reference sites** are relatively unimpaired sites that can be used to define the best physical habitat, water quality and biological parameters for each kind of river.
- **Monitoring sites** are commonly those sites identified as important in assessing the condition of a river or reach, for example a site selected on a river reach known or thought to be experiencing an impact on water quality or habitat degradation.

The emphasis during the initial development and implementation of the NAEBP should be on establishing a useful database of reference sites. Therefore, a detailed protocol for the selection of reference sites is provided.

Selecting indicators to measure

Several biological and non-biological indicators are considered appropriate for inclusion in the NAEBP. Biological indices for fish and invertebrate communities as well as riparian vegetation are described. Non-biological indices for habitat conditions, hydrological characteristics, water quality and the geomorphology of rivers are included.

Five alternative biomonitoring protocols (BP's), ranging from the use of a single biological index and an associated habitat index, to the use of several biological and non-biological indices, are proposed. This is to accommodate a range of regional requirements, capabilities and the availability of resources in the implementation of the NAEBP.

Storing and using biological data

The success of the NAEBP will to a large extent be determined by the effectiveness of communicating results to the different target audiences. The storage, retrieval and interpretation of the data, as well as the presentation and dissemination of the resulting information is, therefore, of utmost importance. The use of a centralised database is envisaged for the national programme. This implies a need to standardise data structures and develop high-speed and reliable data links.

Implementation design phase

The implementation design will aim at developing procedures and infrastructures for implementing and maintaining the NAEBP programme. This will be done by testing the conceptual design on a small scale, modifying it where necessary and implementing the final implementation design nation wide.

Institutional participation

The design of the NAEBP started as an initiative driven by the DWAF's Institute for Water Quality Studies (IWQS). However, neither the DWAF not the IWQS has the regional infrastructure or resources to implement or maintain the programme on a national basis. To achieve implementation and ongoing maintenance of the NAEBP, shared custodianship and partnerships will be required to accumulate a sufficiently large resource base to sustain the programme.

This document suggests that, in line with environmental mandates, roles and responsibilities, further development, implementation and maintenance of the NAEBP take place under partnership of several national and provincial stakeholders. At a national level, the DWAF, Department of Environmental Affairs and Tourism (DEAT) and the Water Research Commission (WRC) are logical custodians of the programme. At a provincial level, several Provincial Departments (e.g. those for Nature Conservation and Environmental Affairs), the Provincial Offices of the DWAF, Parks Boards, Water Boards and others, could become "operational owners" of the programme at an area-specific level.

National coordination

To ensure proper coordination of programme activities at a national level, the establishment of a National Coordinating Committee (NCC) was proposed and accepted at a recent Consultation Planning Meeting. The NCC will have the following responsibilities:

- to continue with and **coordinate the Implementation Design Phase** of the NAEBP, including the setting of guidelines and minimum requirements for provincial and local participation;
- to compile and execute **communication and marketing strategies** for different target audiences;
- to coordinate all **research and development** (R&D) regarding the NAEBP, including the development, testing and standardisation of methods and protocols and the creation of structures for the storage of data;
- to develop and implement **funding models**, specifically regarding national and international sources of funding; and
- to coordinate the availability of **training opportunities.**

Provincial implementation

A **Provincial Implementation Team (PIT)**, representing authorities and stakeholders within a particular provincial region, would be best suited to implement and own the NAEBP in that region according to the available capacity, expertise and needs within that province.

The PIT would primarily be responsible for:

- institutionalising the NAEBP within partaking institutions and organisations in the relevant geographic area, in terms of budgets, resource development priorities, policy planning, etc.;
- implementing and maintaining the NAEBP within the relevant geographic area;
- managing operational resources and infrastructures - human capacity creation, hardware, software, equipment; and
- developing and implementing funding models, specifically regarding provincial and local sources of funding.

A vision for the future

The long-term vision of the NAEBP has been formulated as follows:

Implement, maintain and improve the NAEBP
for all inland aquatic ecosystems in South Africa
and throughout the southern African region.

Future programme goals

In view of the above vision, the future programme goals are as follows:

Short-term (one to three years)

- Test and finalise the programme design for riverine ecosystems.
- Implement and demonstrate the NAEBP for rivers, in at least three to four provinces.
- Launch projects for designing programme components for different types of freshwater ecosystems, i.e. impoundments, wetlands and lakes.
- Liaise with other southern African countries regarding their collaboration with and adoption of the NAEBP.
- Progress towards expanding the implementation of the NAEBP for riverine ecosystems across southern Africa, starting with Lesotho and Swaziland.
- Integrate all the relevant research, development and implementation activities into the framework of national coordination and provincial implementation.

Medium-term (three to six years)

- Implement and maintain, in a sustainable way, the NAEBP for all key riverine ecosystems within South Africa.
- Expand the implementation of the NAEBP for rivers to key river systems in other parts of southern Africa.
- Finalise conceptual designs and test NAEBP for impoundments, wetlands and lakes.

Long-term (more than six years and ongoing)

- Maintain and improve, in a sustainable way, the NAEBP for all freshwater ecosystems in South Africa and throughout the southern African region.

Strategic issues and action plans

Each of the following areas of responsibility are addressed in some detail in the document:

- C Develop and implement funding models
  - areas for funding
  - resource allocation
  - potential funding sources
  - time frames
- C Implement the NAEBP
  - the need for coordination
- C Communication and marketing
  - direct communication campaign
  - information campaign
  - media liaison and publicity
  - educational programmes
- C Research and development
  - further development
  - testing and verification
  - integration, standardisation and quality control
- C Training requirements

Conclusion

The NAEBP provides a structured framework for incorporating aquatic biomonitoring techniques into the assessment and management of water resources. A critical factor for the long-term success of this monitoring programme is sufficient support from national authorities to allow proper testing and implementation of the relevant protocols. Once implemented, the programme should be maintained by provincial and local authorities who require the information to properly manage the water resources in their area of responsibility.

Chapter 1

Introduction

Background

Water, the basic resource

Water is the basic resource upon which society relies for the quality of its life, including its health and recreation. The Department of Water Affairs and Forestry (DWAF) views aquatic ecosystems as the pillars upon which social and economic developments are based and sustained. Aquatic ecosystems must, therefore, be effectively managed and protected to ensure that they retain their inherent vitality and remain fit to provide in the basic needs of humans, as well as to support economic development.

DWAF to safeguard the health of aquatic ecosystems

As custodian of the water resources in South Africa, the DWAF is the primary agency responsible for their ongoing management. Part of the Department's goal is to safeguard the health of aquatic ecosystems. The DWAF therefore seeks both to maintain existing, healthy ecosystems, as well as to improve or restore those ecosystems which are impaired beyond their desired state.

Effective decision-taking and resource management depend, however, on the information provided by effective resource monitoring. Therefore, the development and application of monitoring techniques plays a critical role in the ongoing process of harmonising human welfare, environmental protection and economic development.

Monitoring the effects of multiple stressors

Traditionally, information gathered to assist the management of water resources was predominantly non-ecological in nature. Monitoring actions focused largely on chemical and physical water quality variables, and regulatory efforts were aimed at controlling individual **physico-chemical stressors**. A key assumption made in this type of monitoring is that measurable improvements in water quality will result in an improvement in ecosystem condition.

The measurement of only physical and chemical water quality variables cannot, however, provide information on the overall condition of an aquatic ecosystem. Chemical monitoring alone is insufficient to detect, for example, the cumulative and/or synergistic effects on aquatic ecosystems resulting from multiple stressors. Many factors other than chemical water quality may have an influence on the ecological state of an ecosystem. These factors include habitat alteration, flow regulation, abstraction of water and the introduction of exotic species. Effective management of aquatic ecosystems must therefore address the effects of all these changes, including impacts of effluent discharges on water quality, abstraction of water, creation of barriers that alter stream flow, land-use changes affecting habitat characteristics, and others.

New monitoring approach

In recognition of the integrated and complex nature of ecosystems, the monitoring and management focus of the DWAF has largely shifted from a regulatory "end-of-pipe" approach to a more integrated ecosystem management approach. This has resulted in monitoring needs that increasingly concentrate on the overall response of the environment to stressors, arising from both natural and human-induced processes.

Biological monitoring or biomonitoring techniques can be used to assess the overall health of, and quantify the impacts on, aquatic ecosystems. The current lack of biological indicators in DWAF's monitoring activities is being addressed through the design of a National Aquatic Ecosystem Biomonitoring Programme (NAEBP).

Objectives of this document

In this document

This document provides:

- C background to the need for a national biomonitoring programme and an overview of the rationale that led to the initiation of the NAEBP (Chapter 2),
- C the methodology which was adopted for designing the NAEBP (Chapter 3),
- C framework specifications for the design of the programme, considering the objectives of, and the main considerations that influence, the design (Chapter 4),
- C a conceptual design of protocols and procedures for the programme (Chapter 5),
- C an organisational model for testing, demonstrating and implementing the conceptual design (Chapter 6),
- C an overview of some strategic issues and possible action plans for the next developmental phase of the NAEBP (Chapter 7).

Chapter 2

Monitoring and Managing the Health of Aquatic Ecosystems

Managing aquatic ecosystems

Definition of an ecosystem

An ecological system or ecosystem can be defined as "any unit that includes all of the organisms (i.e. the community) in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycles (i.e. exchange of material between living and non-living parts) within the system" (Odum, 1971).

Ecosystems thus include the physical and chemical (abiotic) environments in addition to biological components. Aquatic ecosystems provide a medium for habitation by aquatic organisms and sustain aquatic ecological processes. These ecosystems also provide drinking water for terrestrial wildlife and water for maintaining riparian biotas and processes.

Social, economic and ecological elements of ecosystems

In managing aquatic ecosystems, social, economic and ecological factors must be considered in their inter-related nature. The social element includes the concepts of beauty, value, history and relevance. These concepts must be defined by the beholder, and are derived from cultural norms and expectations as they relate to natural systems. The economic element includes aspects such as resource use, manufacturing, distribution and consumption. The ecological element of an ecosystem includes factors such as species diversity and abundance, the structure, stability and productivity of ecosystems and the ability of ecosystems to self-organise and evolve.

The DWAF's dual goal to safeguard the health and ensure the sustainable use of aquatic ecosystems, incorporates all three (social, economic and ecological) elements of ecosystems (**Figure 1**).

Figure 1

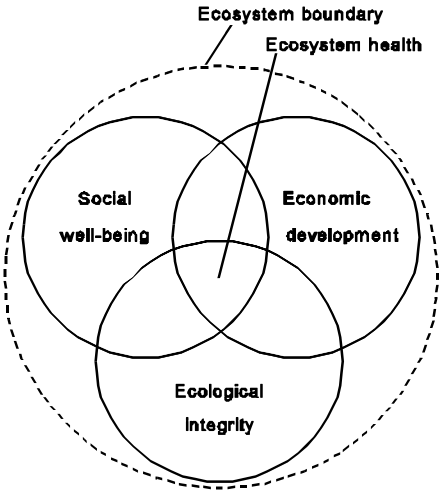


Figure 4: The inter-relatedness of the ecological, social and economic elements of an ecosystem.

Ecosystem health

As human value judgements are an integral part of assessing health, ecosystem health is based on perception and individual judgements rather than universally accepted measurements. In practice there is a need to define, then quantify what people expect from, and what government does about, ecosystem health. However, a composite indexing system for measuring **ecosystem health** is, at the current level of ecosystem science, not available. The ecosystem concept is, therefore, often broken down to its three basic components (ecological, social and economic) for separate measurement and evaluation.

Ecological integrity

In order to find a balance that will sustain ecosystem health, management decisions regarding ecosystem health rely upon expert input from each of the three ecosystem components. The collection of appropriate and adequate data, of dependable quality, is essential to generate the kinds of information that will effectively guide decision-making in the ecosystem arena. The basis, adopted by DWAF, for measuring and assessing the ecological component of aquatic ecosystems, is **ecological integrity**.

Indicators for measuring ecological integrity

What is ecological integrity?

"Integrity" generally refers to a condition of being unimpaired, i.e. corresponding with an original condition (e.g. Weber's Third International Dictionary). Ecological integrity can be defined as 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 characteristics of ecosystems within a specific region. In simpler terms, ecological integrity implies that the structure and functioning of an ecosystem are unimpaired by anthropogenic (human-induced) stresses.

What are ecological indicators?

Ecological indicators are characteristics of the environment, both biotic and abiotic, that can provide quantitative information on the condition of ecological resources. Such indicators can be used to measure and quantify ecological changes in an ecosystem.

Factors influencing ecological integrity

There are five major classes of environmental factors that may affect the ecological condition or integrity of aquatic ecosystems, namely chemical variables, flow regime, habitat structure, biotic interactions and energy sources. Alterations to the physical, chemical or biological processes associated with these factors can adversely affect the ecological integrity of the water body. **Figure 2** illustrates how these factors, as a result of natural events or anthropogenic (people's) activities, can have an impact on the ecological integrity of an aquatic ecosystem. In the assessment of **overall** ecological integrity, it is clear that a suite of indicators needs to be considered.

Figure 2

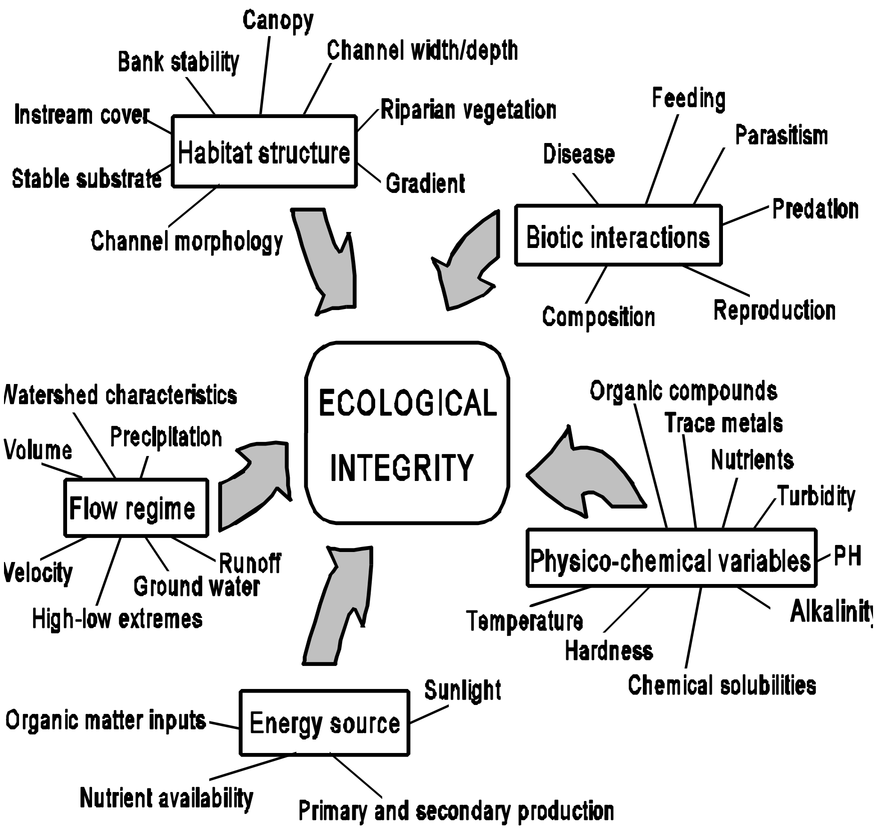


Figure 5: Some of the important chemical, physical and biological factors that influence ecological integrity (modified from Karr *et al*., 1986).

Measuring ecological integrity

Because of practical limitations in terms of available time, money and human resources, it is impossible to measure and monitor all possible contributors to overall ecological integrity. Efforts to assess ecological integrity thus need to focus on indicators that will identify perturbations in an integrated manner.

Indicators of ecological integrity

The in-stream biological condition of a river ecosystem is determined by a multitude of factors, including its geomorphological characteristics, hydrological and hydraulic regimes, chemical and physical water quality and nature of the riparian vegetation. Since resident aquatic communities "integrate" and reflect the effects of all these and other chemical and physical impacts occurring over extended periods of time, they are regarded as good indicators of overall ecological integrity.

Employing the broad-based approach provided by biomonitoring, especially if doing so on a national scale, is thus more likely to be a cost-effective way of providing water resource managers with the much needed ecological information.

Tailoring a biomonitoring programme

When designing a monitoring programme, attention should be given to aquatic community components that are representative of the larger ecosystem and are practical to measure. In determining the taxonomic group(s) appropriate for a particular biomonitoring situation, the advantages of each group must be considered along with the objectives of the programme. The taxonomic groups may also vary depending on the type of aquatic ecosystem being assessed. For example, benthic macro-invertebrates and fish are often used to assess flowing waters, while plants are used in wetlands and algae and zooplankton in lakes and estuaries. The design of a biomonitoring programme should be tailored for the particular type of water-bodies assessed (e.g. wetland, lake, stream, river or estuary).

Non-biological indicators

The above rationale for focussing on **biological indicators** does not mean that other ecological indicators should be ignored. Information derived from **non-biological indicators** are often supportive in the interpretation of biological results. Furthermore, protecting ecological integrity requires the monitoring and protection of the physical and chemical habitats that shape the structural and functional attributes of biota. For this purpose, qualitative and quantitative information on habitat characteristics is required.

Biological indices

For the purpose of disseminating results of a monitoring programme, the information resulting from measuring ecological or biological indicators should be integrated to a point where it can be of use to resource managers, conservationists and the general public. This can be done with a **biological index** which integrates and summarises ecological data within a particular indicator group. Biological indices are used to quantify the condition of aquatic ecosystems, and the output format of the resulting information is usually numeric. Appropriate indicators, for example selected fish community attributes, need to be tested and justified, and linked to measuring units (metrics) that can be used to index biological and ecological condition.

Aquatic biomonitoring

The concept of biomonitoring

Biological monitoring or biomonitoring is based on the assumption that measurement of the condition of aquatic communities can be used to assess the condition of the associated ecosystem. In the operational context, the term **aquatic biomonitoring** refers to the gathering of biological information in both the laboratory and the field for the purpose of making some sort of assessment, decision or in determining whether quality objectives are being met regarding an aquatic environment.

Whereas chemical data are biased towards short-term conditions that exist at the time a sample is collected, biological communities inhabit rivers continuously, and integrate and reflect the effects of chemical, biological and physical influences occurring over extended periods of time. The monitoring of biological communities offers a holistic ecosystem approach, in which the focus of interest is on the ecological resource. In essence the emphasis shifts from focusing on the stressors causing ecological change to include also the effects characterising the change. Biological responses can thus be used to monitor the effects of changing ecological conditions.

Purposes of biomonitoring programmes

Aquatic biomonitoring programmes are developed for various purposes, including the following:

- surveillance of the general ecological state of aquatic ecosystems;
- assessment of impacts (before and after or upstream and downstream of an impact, both for diffuse and point-source impacts);
- audit of compliance with ecological objectives or regulatory standards; and
- detection of long-term trends in the environment as a result of any number of perturbations.

An aquatic biomonitoring programme for South Africa

The need to monitor

As water resource managers are continually faced with increasingly complex challenges, they constantly need different and new types of information to support their decision-making. This progression in information requirements is reflected by the National Water Quality Monitoring Programmes which have been initiated by the DWAF over the past decades. Examples of these programmes are for the monitoring of:

- salinity,
- eutrophication,
- toxic algae,
- radioactivity, and
- faecal pollution.

A new programme

To address the current need for information regarding the overall response of the aquatic environment to multiple stressors, the DWAF has launched an initiative to develop a national programme for monitoring the *health of aquatic ecosystems.*

The new programme is known as the National Aquatic Ecosystem Biomonitoring Programme (NAEBP). The remainder of this document discusses the progress regarding the development of the programme to date, and makes suggestions for the national implementation of the NAEBP.

Note: In previous documents, this programme has also been termed the National Biomonitoring Programme (NBP) or South African National Biomonitoring Programme (SANBP). These names were, however, found to be misleading in instances, as they do not explicitly express that the focus of this programme is limited to **aquatic ecosystems**.

Chapter 3

Design of a NAEBP for South Africa

Introduction

Introduction

This chapter deals with the philosophy behind and methodology of the design process which was adopted. The three main design phases are briefly introduced. More detailed discussion of these phases can be found in Chapters 4 to 6.

This chapter deals with the following sections:

- The design methodology
- Phasing of the programme design.

The design methodology

Components of a monitoring programme

A monitoring programme is usually developed in response to a need for information. The programme design *per se* will, however, not provide the required information. The design needs to be implemented, and the programme must be maintained and modified through ongoing learning, to match our evolving information needs. The design will consist of tools, protocols and methodologies which will be needed in the implementation, and which will make the programme functional. Furthermore, the selection of these tools will be guided by an overall vision and specific objectives for the programme. Lastly, when the programme has been designed, many individuals and organisations may play a role in turning the design into an operational programme which will produce the information it has been designed for.

There is a strong analogy between these interdependent components of a monitoring programme and the "architecture" of a learning organisation, as proposed by Peter Senge in *The Fifth Discipline Fieldbook.* Following this architectural analogy, the main components in the development and implementation of a monitoring programme are:

- **guiding ideas** - the architectural drawing which guides the development of the programme,
- **theory, methods and tools** - the bricks which are used in constructing the programme, and
- **innovations in infrastructure** - the cement which keeps the programme together.

The model presented in **Figure 3** can be used to explore the specific functions of, and the relationships between, the components of a monitoring programme.

Figure 3

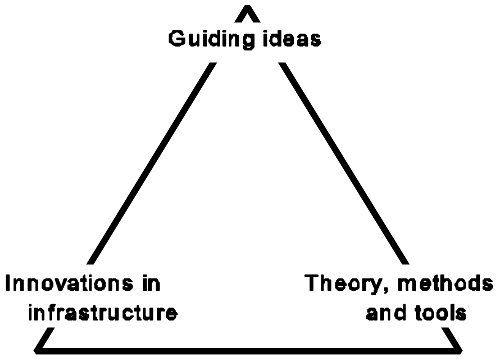


Figure 6: The architecture of a long-term monitoring programme (adapted from Peter Senge's *The Fifth Discipline Fieldbook*, 1995).

Guiding ideas

The ideas which guide the design of a monitoring programme are borne from a shared knowledge, understanding and vision, by those who need the information to be generated by the programme, of:

- why the programme is needed,
- where the programme should take them, and
- what is required to make the programme a reality.

The guiding ideas are not borne at the spur of the moment, but are characterised by philosophical depth which usually matures over a long period of time. At the same time these ideas should be subjected to constant testing and review to ensure their ongoing improvement and relevance. Thus, the guiding ideas are not static.

Theory, methods and tools

To implement the theory of biomonitoring, various methods and tools are needed to, for example, conduct biological measurements, interpret these measurements and present and disseminate the resulting information. Tools which are based on a strong underlying theory are more likely to be widely applicable and survive for a longer time. The “architects” designing the programme should be explicit about the capabilities and limitations of the tools.

Innovations in infrastructure

Good guiding ideas and sound methods and tools are not sufficient to ensure the successful implementation of a monitoring programme. Infra-structural mechanisms must be developed and improved to ensure the long-term feasibility of the programme in terms of required resources: political and management support, expertise, money, equipment, people, time, etc. Such mechanisms are most likely to be achieved through organisational arrangements for co-participation and coordination in the development and implementation of the monitoring programme.

Phasing of the programme design

Phased approach

A phased approach was adopted for the design of the biomonitoring programme, to facilitate the formulation of a design framework (based on guiding ideas), the conceptual development (theory, tools and methods), testing and demonstration and eventual full-scale implementation (through innovations in infrastructure) of the programme (see **Figure 4**).

Figure 4

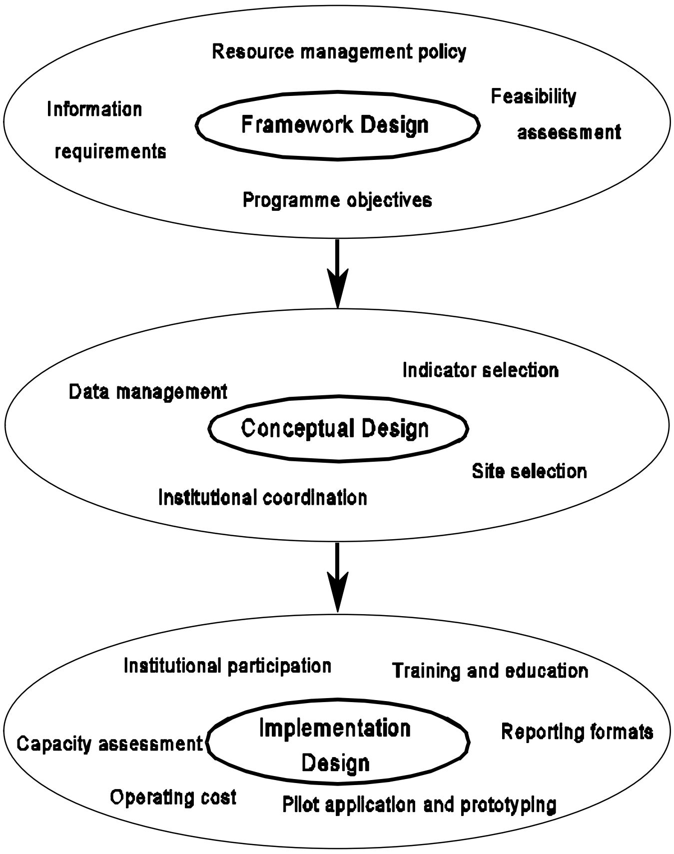


Figure 7: The main design phases adopted for the development of a National Aquatic Ecosystem Biomonitoring Programme (NAEBP).

Framework design

The framework within which the NAEBP was to have been designed was specified based on two aspects, namely:

- the qualitative and quantitative information requirements related to the management of aquatic ecosystems, as expressed by aquatic resource managers, and
- the ability of a national-scale biomonitoring programme, at the current level of scientific development, to deliver the required information.

An important outcome of the framework design was a definition of the objectives of the programme as well as the scope and specification to which the rest of the design phases must adhere (see Chapter 4).

Conceptual design

During the conceptual design phase, aspects which were addressed included the development of:

- a spatial classification scheme, which would allow the delineation of geographical areas within which it would be valid to compare biological data from different sites;
- a protocol for selecting reference and monitoring sites to support state-of-the-environment (SOE) reporting;
- protocols for selecting and using biological and other ecological indicators to measure the health of river systems;
- procedures for the transfer, storage and retrieval of data resulting from the NAEBP;
- mechanisms and structures for institutional coordination, which is essential for the long-term maintenance of any national environmental monitoring programme.

(For detailed documentation of the above protocols and processes, see references to NAEBP Report Series listed in Appendix A)

It is important to realise that, in the conceptual design phase, these developments are largely theoretical, and that substantial testing, modification, demonstration and integration are still required to mould all the concepts into an operational programme.

Implementation design

The implementation design phase is about matching the ideals of the conceptual design with the realities of the real world, in order to create a feasible platform for implementing and maintaining the NAEBP. During this phase all the components of the conceptual design must be tested in order to allow the required modifications before full-scale implementation commences. Pilot testing also allows small-scale demonstration of the programme through reporting the generated information to key target audiences. Additional research and developmental needs will, furthermore, be identified during this phase.

The final implementation design must provide the information required to implement and maintain the programme successfully. It must, therefore, address aspects such as start-up cost, operating cost, human resource requirements, training needs, institutional participation, equipment needs and maintenance requirements.

Chapter 4

Framework Design for the NAEBP

Introduction

Introduction

The framework design is influenced primarily by two factors, namely the information required from the programme and the technical and practical feasibility of delivering that information. Both of these factors can change with time, for example, as information expectations evolve and new monitoring techniques become available. As such, the framework design is an iterative and ongoing process, and should periodically be revisited to update the design specifications.

In this chapter the broad design specifications and objectives of the NAEBP are presented. Two key concepts which flow from the programme objectives, namely the assessment of measured data and the use of area-specific benchmarks for assessment, are discussed in more detail.

Design specifications

A management information system

The NAEBP is being designed primarily as a *management information system*. The approach of designing programmes as management information systems recognises that the ultimate purpose of a monitoring programme is to produce information for a specific objective. In the case of the NAEBP the information must support the management of water resources.

National versus local information needs

A survey of information requirements, conducted among water resource managers, revealed the following:

National requirements

- to determine the **state of health/protection** - this implies a need to rate or classify aquatic ecosystems in some way to assign a relative value to the condition of the system;
- to determine **trends in the state or health** of ecosystems, i.e. are they improving, recovering, stable, declining, etc.

Provincial / catchment-based / local requirements

- to identify where **impacts** are taking place, for example, a decline in sensitive species could act as an early warning system of a degradation of the river resource;
- to assist in setting specific **objectives** for rivers, perhaps based on a river classification scheme;
- to measure and evaluate the impact of **developments** (planned and actual) on ecosystems;
- to monitor the effects of implementing a development in order to provide data for **predictive modelling** purposes, especially for determining the impact of other similar developments.

It is unlikely that one biomonitoring programme will meet all information needs. As the NAEBP is required to provide information on a national level, its design must be specified accordingly. As such, it was agreed by managers that the primary focus of the NAEBP should be on the **state of health** of aquatic ecosystems.

Relation to existing monitoring programmes

The NAEBP is not intended to replace any existing water quality monitoring activity, but rather to supplement and extend current water quality monitoring and assessment strategies. The incorporation of biomonitoring into the current national water monitoring network will, however, bring about a far more integrated collection and analyses of data, as well as the assessment of new types and combinations of data. The implementation of a NAEBP would, therefore, provide a substantial broadening of the traditional water quality monitoring and assessment focus.

Initial focus

An extensive national programme to monitor the health of aquatic ecosystems will eventually cover all types of aquatic systems, for example rivers, impoundments and wetlands. Designing a monitoring programme for different types of systems will, however, require different types of expertise. It was decided to focus initially on one type of system, namely rivers. The knowledge and experience gained through the development of a biomonitoring programme for riverine ecosystems can then be extended to incorporate other types of aquatic systems.

International approaches

Several approaches to the design and implementation of biomonitoring programmes have been followed over the world. The most noteworthy of existing programmes are:

- the British River Invertebrate Prediction and Classification (RIVPACS) methodology;
- the Australian National River Health Programme; and
- the Environmental Monitoring and Assessment Programme (EMAP) of the United States.

The programme being designed for South Africa will incorporate appropriate concepts and components from these international models, yet be tailored to reflect the unique environmental conditions and resource realities of this country.

Biological versus ecological indicators

Biological indicators, i.e. biological communities, reflect the integrated effects of chemical and physical water quality, habitat conditions, hydrological regimes, etc. Biological indicators can thus provide an overall picture of ecological conditions. However, information regarding the non-biological indicators of aquatic ecosystems often supports the interpretation of biological results. Information on these other ecological indicators may also provide important decision support regarding the management of aquatic ecosystems.

Although the monitoring focus of the NAEBP will be on biological indicators, relevant non-biological indicators should also be incorporated to have a suite of ecological indicators for assessing aquatic ecosystems.

Operational responsibility

The operational management and coordination of National Monitoring Programmes are the responsibility of DWAF's Institute for Water Quality Studies (IWQS). As the IWQS does not have the national infrastructure to support these programmes, extensive use is made of agents such as the DWAF's Provincial Offices and Water Boards. Increasingly, those departments of Provincial Governments with responsibilities for environmental management are becoming involved in these monitoring activities.

Models for coordination and co-participation among relevant organisations will have to be investigated. It will be necessary to pool and optimise available resources and capabilities in order to successfully implement and maintain a national programme of the complexity and specialised nature of the NAEBP.

Objectives of the NAEBP

Objectives of the NAEBP

The main objectives of the NAEBP are to:

- measure, assess and **report on the ecological state** of aquatic ecosystems,
- **detect** and report on spatial and temporal **trends** in the ecological state of aquatic ecosystems, and
- **identify** and report on emerging **problems** regarding the ecological state of aquatic ecosystems in South Africa.

Each of these objectives are discussed in more detail below.

Report on the ecological state

The level of information which would be available to report on, would be determined by the breadth and detail of the data that are collected. “Breadth” depends on the number of ecosystem processes and components (indicators) that are included in the data. “Detail” refers to the degree to which each ecosystem indicator is measured and analysed. The more detailed the available data, the better the insight that can be obtained about the functioning of the ecosystem, i.e. the interrelations among ecological components as well as their relationship to stressors.

Current ecological knowledge does not allow for obtaining a complete picture of ecosystem components and all the processes associated with them. Therefore, a compromise has to be made between the breadth of the information and the degree of detail. Breadth is often at the expense of detail. A broad approach can be sensitive to all kinds of stressors, however, subtle responses may not be detected. Similarly, detail is at the expense of breadth. Although diagnostic capacity depends on the detail of information, the evaluation may become too narrowly focused, with an increasing risk that important effects on other ecosystem components can be overlooked. Also, there comes a point at which too much detail can cloud the issue or make analysis unnecessarily complex.

Ultimately, the breadth and detail of monitoring specifications need to be tailored according to resource realities. On a national scale, the programme will be designed to measure and assess the general state and annual changes over river reaches, rather than to provide day-to-day operational answers or for measuring exact river conditions at any specific site.

Detect trends

Natural ecological variation will complicate direct comparison of monitoring results between sites. However, through the development of a spatial classification scheme, it is hoped that geographical areas could be delineated within which it is valid to compare data from different sites. Normalising the conditions at each site, relative to a benchmark or reference condition for the particular geographical area, will allow direct comparison and the detection of spatial trends in the ecological state among sites.

Once the programme has been in existence for a few years, the detection of temporal trends should provide an ability to quantify improvement/deterioration, or to qualitatively predict ecosystem degradation.

Identify problems

The data collected through a national programme are unlikely to be sufficient to establish causal relationships with a high level of confidence, i.e. specific detail on impairment due to habitat degradation, hydrological alteration or chemical water quality deterioration. Therefore, to address questions related to emerging problems, the national programme needs to feed into regional or site-specific bio-assessment initiatives, tailored for the particular problem experienced. More detailed and frequent monitoring can be instituted to provide answers to specific questions as part of such specific studies. An example of such a question may be the extent to which the quality of an effluent discharge must be improved in order to achieve a specified in-stream ecological objective.

Whereas national-level ecological indicator surveys should allow the detection of unacceptable change, regional-level detailed surveys would be required to link, with a significant level of confidence, specific causes to the change. National assessment would thus allow limited resources to prioritise regional activities and to focus on specific problem areas. Although regional biomonitoring activities will not be addressed as part of the national programme design, regional-level bio-assessment will be essential to complement the information derived on a national level and hence to optimise decision-making competence. Provision must, therefore, be made for linking national and regional bio-assessment programmes.

The concept of environmental assessment

Measure and assess

Ecological indicators can be used to **measure** changes in ecosystems, and these measurements can in turn be used to **assess** the implications (or consequences) and acceptability of such change. For the purpose of designing a monitoring programme it is, therefore, important to distinguish between measurement end-points and assessment end-points.

Measurement end-points

A **measurement** end-point is the result of an actual measurement of some ecological response to a stressor(s). Measurement end-points can be seen as characteristics of an ecological indicator, for example the mortality of a fish population, that may be affected by exposure to a stressor. The values generated through indices of water quality are further examples of measurement end-points.

Assessment end-points

An **assessment** end-point is the result of an interpretation (assessment) of measured data, often in conjunction with other related data. Assessment end-points are explicit expressions of an actual environmental value which bears direct relation to the management of ecological resources. An example is where measured indicator values for impacted and unimpacted sites are assessed to express the degree and/or acceptability of impairment at the impacted site.

A value-added perspective

Environmental assessment provides a synthesis and interpretation of scientific information, and can often be linked with policy or regulatory questions and issues. Environmental assessment is usually characterised by a value-added perspective, ranging from a formal, quantitative cost/benefit analysis of all alternatives to a qualitative improvement in our understanding of potential impacts or effects.

The measurement and assessment concepts have important implications for a monitoring programme, which must:

- reflect and describe the relationship between measurement and assessment end-points,
- describe in sufficient detail the assessment process so that different people using the same measured information will consistently arrive at the same assessment, and
- recognise that for the purpose of management decision-taking, information has to be reported in the form of assessment rather than measurement end-points.

Area-specific benchmarks for assessment

Ecosystems are dynamic

Ecosystems are naturally dynamic, and their evolutionary histories and capabilities are never static in either structure or function. For example, hydrological regimes are variable on many time scales, and include not only the "normal" range of conditions at a site, but also the "extremes" of floods and other infrequent conditions. From an ecological point of view there is, however, nothing abnormal about these extremes. These occurrences are a natural and often crucial part of ecosystem dynamics, especially over the long-term.

Ranges of ecological variation

When interpreting the results from an ecosystem monitoring programme, the challenge lies in distinguishing between natural and unnatural ranges of change in measured ecological values. Managers will benefit from the knowledge that an ecosystem is responding in some way that is outside its natural range of variation. This would allow remedial steps to be taken before such change becomes permanent. One way of distinguishing between natural and unnatural ranges of variation, is to establish a "natural" benchmark or reference condition which can be used for evaluating similar monitoring sites against.

In general, assessing the state of a river requires a procedure for comparing the current state of the ecosystem with a benchmark or reference condition. This means that both the state of the ecosystem to be assessed and the reference conditions have to be made explicit.

Reference conditions

In South Africa, establishing reference conditions is made more complicated by a large range of ecosystem types. The variability among natural surface waters, resulting from vast climatic, landform, land cover (vegetation), soil type and other geographic differences, favours the use of area-specific reference conditions, rather than national reference conditions. Such area-specific reference conditions should describe, within the relevant region, the characteristics of river segments least impaired by human activities, in order to define attainable biological or habitat conditions. The development of area-specific reference conditions will allow environmental conditions at any site(s) under investigation to be compared with conditions found or expected in undisturbed streams or rivers, of similar size and habitat type, and located in the same area.

As completely undisturbed environments are virtually nonexistent, and even remote waters are impacted by factors such as atmospheric pollution, "minimally impacted" sites have been used (for example in the United States) to define the "best attainable reference condition". However, care should be taken in cases where the best site(s) in a region is already considerably modified. In such cases, expert knowledge and extrapolation techniques may be required to construct a hypothetical "best attainable" condition, which can be used as a regional reference.

Assessing current conditions

Once appropriate benchmarks have been set for a particular region, standardised indices for measuring ecological integrity can be used and the resulting data can be compared against these regional reference conditions. **Figure 5** shows how the results obtained at reference sites can be used to calibrate biological indices. Whereas the reference condition represents the top end of such a calibrated scale, an almost sterile system will represent the lowest possible state. A regional calibration of ecological state will enable the assessment of the current ecological state of any site or reach within that region. The current state for a particular site can be anywhere between the reference state (100%) and the lowest possible state (0%).

Figure 5

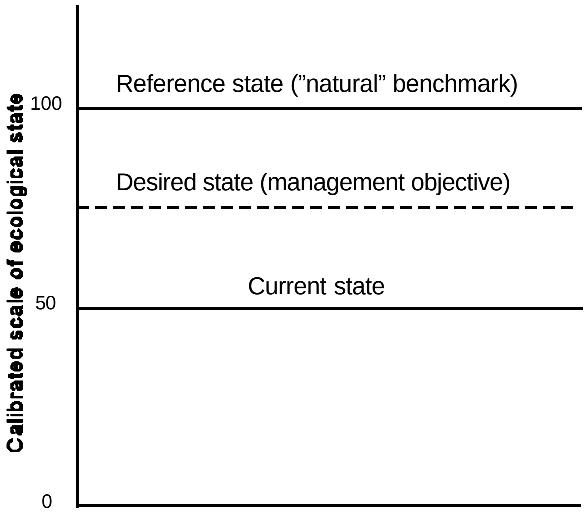


Figure 8: A conceptual model for assessing the ecological state of an aquatic ecosystem.

Setting management objectives

Area-specific conditions, based on the inherent biological potential within a region, will help resource managers to set environmental objectives for the restoration and protection of rivers in a way that is ecologically feasible.

Apart from a reference condition and the current ecological state, a future desired state can also be fitted to the calibrated scale in **Figure 5**. The desired state reflects the ecological values we seek to protect, and should be translatable into management objectives. Following the goal of DWAF to maintain or improve ecosystem health, the desired state should be the same or better than the current state. The desired state may even be similar to the reference state, depending on the ecological importance associated with a particular ecosystem. However, making choices about the desired state entails more than the assessment of measured data, and requires input from all stakeholders.

Chapter 5

Conceptual Design for the NAEBP

Introduction

Introduction

This chapter provides a summarised overview of the programme specifications which have been developed to date. **More detailed information on the development of a spatial framework for site selection, a protocol for the selection of reference and monitoring sites and protocols for selecting indicators can be obtained in published programme reports (see appendix on sources of information and further reading)**.

A spatial framework for selecting sampling sites

Where to sample?

During the conceptual phase of development of a NAEBP for South Africa, attention was focused primarily on general SOE reporting, as opposed to specific monitoring of problem areas (impacts assessment). The emphasis on long-term SOE monitoring necessitates a network of sites which are representative of the full range of variation in character of rivers within the country.

Internationally, the problem of selecting representative sites to encompass the complete range of variation in river character has been approached in two broad ways. These can be described as being either "multivariate" or "regional" approaches.

The multivariate approach

The British RIVPACS methodology is based on the multivariate approach, and can be summarised as follows:

- Relatively unstressed reference sites are selected, based on water quality data and expert opinion.
- Environmental and macroinvertebrate data are collected at each site, during spring, summer and autumn.
- The macroinvertebrates are identified to the taxonomic level of species.
- The macroinvertebrate data are subjected to multivariate analysis to establish groups of sites with similar macroinvertebrate communities.
- The environmental characteristics of each group of sites are described.
- Macroinvertebrate communities at monitoring sites are compared to those at reference sites with the most similar environmental characteristics, to assess the degree of difference between them.

The regional approach

In the regional approach, riverine ecosystems are grouped geographically on the basis of similarity between their catchments. This concept is based on the assumption that waterbodies reflect the catchments they drain and therefore, catchments with similar characteristics should result in similar waterbodies. In the United States, regions of similarity in terms of their waterbodies have been termed **ecoregions**. Biotic assemblages would be expected to differ among ecoregions but be relatively similar within any given ecoregion.

The regional approach originated in the USA, where James Omernik provided an ecoregional framework for that country based on regional patterns in land-surface form, soil, potential natural vegetation and land use. The different ecoregions can be used as a template for site-selection. Within each ecoregion, a small number of minimally impacted reference sites are selected which are used to derive biological reference conditions for each ecoregion.

Weighing up the approaches

There are arguments for and against both the multivariate and the regional approaches to reference site selection. For example, the multivariate-type approaches are considered to provide a more objective way of identifying groups of reference sites with which monitoring sites can be compared, than do regional-type approaches. However, an extremely large database of the biotic community structure and environmental conditions at many sites is needed in order to create the predictive models on which a multivariate approach is based. Regional approaches, on the other hand, generally require fewer sites than the multivariate approach and promote structured coverage of all types of rivers occurring within a country. In addition, the adoption of a regional approach does not preclude the eventual transition to a multivariate approach when sufficient data become available, whereas the opposite is not true.

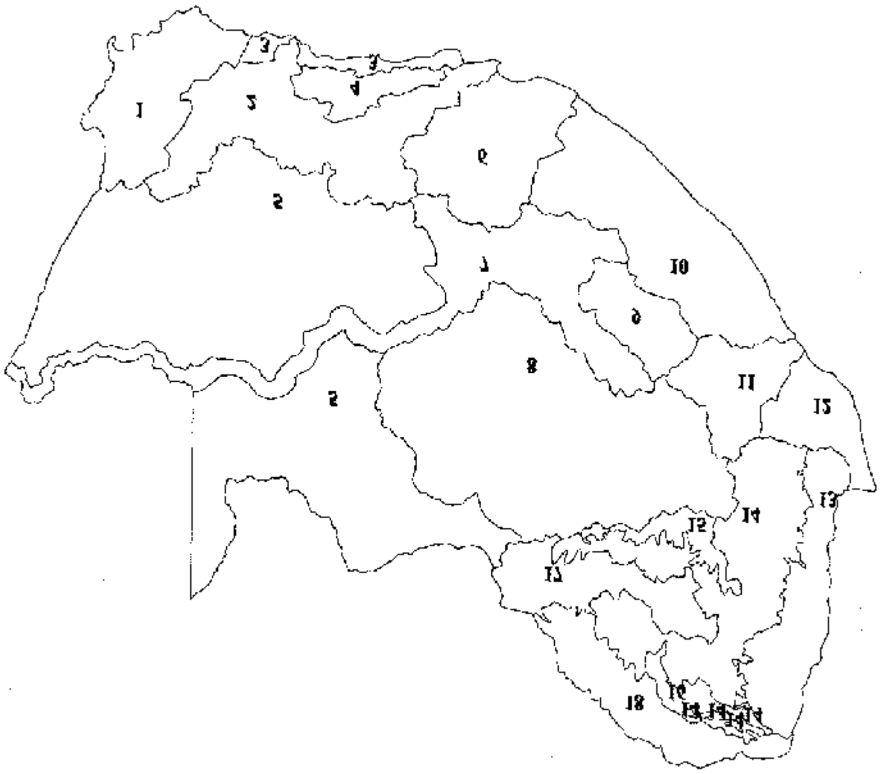
Proposed approach for use in South Africa

It was proposed that the regional approach be adopted in South Africa. An existing **biogeographic classification** of the rivers of South Africa was identified as a useful basis for regional classification. This classification was delineated on the basis of fish, riparian vegetation and macroinvertebrate distribution patterns. However, it was recognised that this classification in itself had too coarse a resolution to meet the requirements of the NAEBP, and that refinement and further sub-division of the biogeographic regions would be necessary.

National workshop

In order to facilitate refinement of the biogeographic regions, a national workshop involving 21 river scientists with experience of rivers in different parts of the country, was convened in Cape Town in January 1996. An important outcome of this workshop was the production of a map of **bioregions** (a modification of the existing biogeographic regions) for South Africa (see **Figure 6**). The workshop also progressed towards a finer resolution of classification, and provided a first estimate of sub-regions and river types for each bioregion.

Figure 6



1 Fynbos	2 Alkaline Interior	3 Southern Coastal
4 Southern Inland	5 Arid Interior	6 Drought Corridor
7 Orange	8 Vaal	9 Montane
10 Eastern Seaboard	11 Tugela	12 St. Lucia Complex
13 Lowveld	14 Northern Uplands	15 Highveld Source
16 Northern Plateau	17 Bushveld Basin	18 Limpopo

Figure 9: Map of South Africa showing 18 bioregions.

A three-tiered hierarchical classification scheme

Following on the outcome of the National Workshop, additional work led to the development of a three-tiered hierarchical classification scheme, as follows:

Level 1 **Bioregional Classification:** a modification of the original biogeographic classification based on the broad historical distribution patterns of riverine macroinvertebrates, fish and riparian vegetation.

Level 2 **Sub-regional Classification:** based on patterns of river zonation within bioregions. It was envisaged that this would reflect agreement between broad geomorphological characteristics (e.g. landform, lithology, soils, hydrology, climate, basin relief, river profile morphology) and distribution patterns of fish, macroinvertebrates and, to a lesser extent, riparian vegetation.

Level 3 **River Types:** which were to account for variation between rivers within a sub-region. It was envisaged that this level of the hierarchy would account for differences in factors such as river size, hydrological pattern (e.g. perennial or intermittent flow) and other geomorphological or chemical characteristics.

(Time and information constraints have so far prevented the mapping of sub-regions and river types, and further work is required to complete and verify the classification.)

A protocol for the selection of reference and monitoring sites

Sampling sites

The NAEBP is being designed to allow comparison between reference and monitoring sites, where:

- **Reference sites** are relatively unimpacted sites that can be used to define the best physical habitat, water quality and biological parameters for each kind of river.

- **Monitoring sites** are commonly those sites identified as important in assessing the condition of a river or reach known or thought to be experiencing an impact on water quality or habitat degradation. In the case of SOE reporting, however, monitoring sites are randomly selected impacted or unimpacted sites that reveal the range of conditions in their types of rivers.

Reference sites

Reference sites represent the best condition that can be achieved in a river of a particular kind, against which the conditions found at the monitoring sites in the same kind of river can be assessed. Reference conditions, as measured at reference sites, play a role similar to that of a "control" in scientific experiments. These conditions provide a credible baseline from which to set targets, assess impacts and determine the success of any rehabilitation programme.

When monitoring sites are compared with reference sites it is assumed (for statistical purposes) that the reference sites are selected objectively. Hence, considerable effort may be required initially to identify reference sites, and to describe the habitat and biological characteristics of the chosen sites.

In the context of a long-term biomonitoring programme, reference sites are more than just site-specific controls against which change can be assessed. They also provide data on benchmark or attainable conditions for the river types they represent, provide data on long-term trends (time-series data) in natural river condition, and allow for the recalibration of predictive models. Hence, the reference sites should be selected under the assumption that, once the validity of their inclusion has been varied, they will be preserved in perpetuity.

Criteria for selecting reference sites

The most important criteria that have been taken into account in selecting reference sites elsewhere in the world are that:

C They should be **representative** of the streams for which they are to provide a reference.

C They should be as **little disturbed** as possible.

C They should be **selected** in an **objective** fashion.

C Sufficient reference sites should be **situated** in areas of the greatest management concern.

Number of reference sites

It is obvious that each river type should be represented by at least one reference site. It would, however, be advisable to have more than one reference site per river type, both to deal with natural variability and to safeguard against destruction of a chosen site. The more reference sites within a river type, the higher the certainty would be of deriving a true reference condition for that river type.

Pragmatic considerations

Procedures for selecting both reference and monitoring sites must be tempered with realism, and all sites should be:

- **suitable** for application of monitoring techniques,
- **accessible**, that is, situated close to access roads,
- selected in order to **maximise information** content.

Additionally, there is no need to establish reference and monitoring sites over the whole country at the same time. The exercise could be initiated in certain areas, for example provinces, and extended as resources permit.

Proposed protocol for selecting reference sites

Within each river type, the proposed process for the selection of reference sites consists of seven steps, namely:

1) the *a priori* selection of least-impacted sites, based on expert opinion and local knowledge, within each of the pre-defined river types;
2) the preliminary screening of the selected sites, by means of field visits, and the elimination of those sites that are notably more perturbed than others;
3) data collection, i.e. rapid-assessment sampling of the biota and physical habitat at the remaining sites;
4) data screening, i.e. multivariate analysis of results of each river type, and elimination of outliers;
5) final selection of reference sites, i.e. statistical analysis of data obtained at the remaining sites to assess: (a) the degree of variability likely to be encountered and (b) the optimal number of sites needed to represent each river type;
6) repetition of the multivariate analysis and elimination of outliers until optimal number of sites remain;
7) testing validity of reference sites by comparing a selection of sites with known disturbance with the reference sites.

Proposed protocol for selecting monitoring sites

The primary focus in the initial development of the NAEBP should be on establishing a useful database of reference sites. However, in the early phases of the programme a few monitoring sites that are known to be impaired should be included in the sampling regime, to test the discriminatory ability of the proposed metric or analysis technique.

In addition to the impaired monitoring sites, a series of sites should be randomly selected to test reporting protocols. These sites could form the core of what will become key monitoring sites for SOE reporting. Although random, this selection of sites should proportionally and adequately represent the river types and existing land-use patterns.

The number of monitoring sites should increase after the design phase of the NAEBP is complete and the programme becomes accepted and integrated with other national monitoring programmes.

Selecting indicators to measure the state of rivers

Indicator selection

A key element in the design of a biomonitoring programme is the decision as to which indicators to measure, and which indices to select to represent these indicators. While biological indicators are the main focus of the NAEBP, the inclusion of physical and chemical indicators will substantially increase the long-term information value of the programme.

The biological indicators most commonly used in biomonitoring are aquatic macroinvertebrates and fish. Riparian vegetation serves to link the instream aquatic ecosystem to the surrounding terrestrial ecosystem which, in turn, influences river process and pattern. Although this component of aquatic ecosystems is often overlooked, riparian vegetation is considered a vital element in determining the state of aquatic ecosystems.

The state of riverine biota is a reflection of the chemical and physical habitat conditions in that river. In order to interpret the meaning of the biological index values accurately, it is necessary to gather information about the chemical and physical environment of the river. These physical and chemical indicators provide a framework within which to interpret the biological results. As an example, the community of fish or invertebrates will be very different in a river with high than in one with low habitat diversity, or before and after a prolonged drought.

The non-biological indicators considered to provide the most comprehensive support framework for the interpretation of biological data are aspects of physical habitat, hydrology, water chemistry and geomorphology.

Biological indicators suitable for South Africa

Several biological and non-biological indicators are considered appropriate for inclusion in the NAEBP. These are as follows:

Fish - Being relatively long-lived and mobile, fish are good indicators of long-term influences on and the general habitat conditions of a river reach.

Invertebrates - Invertebrate communities are good indicators of localised conditions in a river, especially regarding water quality, over the short-term.

Riparian vegetation - Healthy riparian zones maintain channel form and serve as important filters for light, nutrients, sediments, etc. Changes in the structural or functional characteristics of riparian vegetation commonly indicate changes in the flow regime of a river, exploitation for fuel (wood), or the use of the riparian zone for grazing or ploughing.

Non-biological indicators suitable for South Africa

Habitat - Habitat availability and diversity are major determinants of aquatic community structure. Adverse changes in biological communities may be attributed either to deterioration in water quality or to habitat degradation, or to both.

Hydrology - Flow conditions in a river affect the distribution and abundance of biota by creating dynamic habitats characterised by current speed, water depth, and - in the long term - substratum characteristics. The present and recent past hydrological characteristics of a river are considered important indicators of the condition of riverine ecosystems, and in particular the state of biotic communities.

Water quality - The physical water quality variables which potentially affect aquatic ecosystems and their biota include turbidity, suspended solids and temperature; the chemical variables include pH and salinity, and the concentrations of dissolved solids, individual ions, nutrients, dissolved oxygen, biocides and trace metals. Changes in these variables due to pollution, geomorphological or hydrological factors, can have detrimental or even lethal effects on aquatic organisms.

Geomorphology - Geomorphological processes determine river channel morphology, and thus provide the physical framework within which stream biota live. Adjustment to channel form occurs both naturally and as a result of modifications to rivers or their catchments (e.g. impoundments, water importation, agriculture).

Indices for South Africa

For certain of the above indicators, indices have been developed and widely applied in South Africa. For the majority of the indicators, however, indices are in the early phases of conceptualisation and need practical development and testing. As part of the conceptual design phase of the NAEBP, aquatic specialists have been requested to elaborate on criteria for appropriate indices for these indicators, and to design conceptual indices. Their inputs are presented below.

Biological indices

The following biological indices are recommended for inclusion in the NAEBP:

South African Scoring System version 4 (SASS4) - This rapid biological assessment method was developed to evaluate the impact of changes in water quality, using aquatic macroinvertebrates as indicator organisms.

Fish Community Index (FCI) - This index, based on the relative integrity of fish communities, is currently being developed for selected South African rivers. The FCI is broadly comparable with the Index of Biotic Integrity (IBI). The IBI was developed and has been used extensively in the United States.

Riparian Vegetation Index (RVI) - The RVI is based on an index developed in South Africa for the qualitative assessment of the conservation status of riparian vegetation. It is a site-specific approach which places particular emphasis on the functionality or ecological integrity of the riparian vegetation. This is a first attempt at an index of this kind, and review, testing and refinement will be necessary during the course of its further development.

Non-biological indices

The following non-biological indices are recommended for inclusion in the NAEBP:

Index of Habitat Integrity (IHI) - This index was developed to assess the habitat and conservation status of a river at the scale of the reach, zone, or river. This index evaluates the impact of major disturbance factors (e.g. flow regulation, bed and channel modification, water abstraction) on the capacity of the river to provide suitable living conditions for organisms. The occurrence, diversity, quality, variability and predictability of present available habitat is gauged against habitat characteristics which could be expected to occur if the river were not anthropogenically impacted.

Habitat Assessment Matrix (HAM) - The HAM originated from the US Environmental Protection Agency, where it was developed for use at the scale of the monitoring site and as an adjunct to both fish and invertebrate biomonitoring techniques. Adaptions of HAM are used alongside SASS4 macroinvertebrate monitoring and fish monitoring in South Africa. These modified procedures require further development and verification.

Hydrological Index (HI) - The HI has conceptually been designed to provide information on the hydrological context in which biological sampling takes place. This index describes flow conditions both at the time of sampling, and in the period prior to sampling. The development and application of the HI has not yet been field tested, and there is still some uncertainty regarding its eventual structure and application.

Water Quality Index (WQI) - The WQI has been designed specifically for South African conditions. The formulation of the WQI is based on the use of a modified arithmetic weighted mean for a number of selected water quality variables. These variables are rated from a rating curve which relates the observed concentrations to a corresponding rating value between 0 and 100.

continued on next page

Geomorphological Indices (GI) - The geomorphological component of a biomonitoring programme will require an initial classification of the channel to allow, first, comparison between sites and, second, long-term morphological change. Evaluation of change requires the application of an index which is separate but related to the classification. Thus, two indices are recommended, namely a **Channel Classification Index (CCI)** and the **Hydraulic Biotope Diversity Index (HBDI)**. Both these indices are currently being developed.

Proposed biomonitoring protocols

To accommodate a range of regional requirements, capabilities and the availability of resources in the implementation of the NAEBP, five alternative biomonitoring protocols (BPs) are being proposed (BP1 to BP5). The options range from the use of a single biological index and an associated habitat index at a site, to the use of several biological and non-biological indices. The latter option provides a comprehensive assessment of the state of the riverine communities and their environmental conditions. The BPs are constituted as follows:

BP1: SASS4 and associated HAM

BP2: SASS4 and associated HAM + FCI and associated HAM

BP3: SASS4 and associated HAM + FCI and associated HAM + RVI

BP4: SASS4 and associated HAM + FCI and associated HAM **or** RVI + HI **or** WQI

BP5: SASS4 and associated HAM + FCI and associated HAM + RVI + HI + WQI + GI

Once a biomonitoring initiative has started, it would be possible to scale up or down on the BP adopted for a certain catchment, province or the country. Such a decision would depend on the resolution of information required, available resources and expertise, and the possible prioritisation of particular rivers or sites.

Frequency of monitoring

From the time-integrating nature of biological indicators, a much lower biological monitoring frequency is usually required than is the case for chemical water quality variables. The optimum sampling frequency will also vary for different biological indicators, for example invertebrates (with relatively short life spans) will be sampled more frequently than fish (with longer life expectancies). Similarly, the non-biological indicators would be monitored at a frequency concurrent with the time scales in which change in that specific component of aquatic ecosystems is likely to occur. Furthermore, the conservation importance of each river may have a bearing on the frequency of monitoring, especially where limited resources have to be allocated to rivers on a priority basis.

Following are the proposed sampling frequencies for the recommended indices:

Biological indices:

SASS4 - twice to three times per year; preferred sampling times are at the end of the dry season, at the end of the rainy season and during the dry season

FCI - once every three years

RVI - once every three years, to coincide with fish monitoring

Non-biological indices:

IHI - once every five to ten years, depending on the rate of development in a specific area (the more the development, the higher the frequency

HAM - with SASS4 and FCI monitoring

HI - with SASS4 and FCI monitoring

WQI - with SASS4 and FCI monitoring

GI - initially for all rivers, then only after events, such as floods (or major changes to catchment land use), which would cause changes to river morphology.

Storing and using the biological data

Data management

Options for data capturing include:

- filing and distributing hard-copy data sheets,
- updating and maintaining local databases, and
- sharing a centralised database.

The last option is preferred for its advantages in terms of long-term data security and accessibility. The feasibility of this option would, however, depend on a uniform data structure and high-speed and reliable data links. Both of these qualifying aspects are currently receiving attention from the DWAF.

Data ownership

In an on-line and centralised database, data will be part of an open system. It would be possible to acknowledge ownership of the data on the system, although the rights of data owners, for example editing of data on the database, still need to be clarified.

Information users

Information derived from the NAEBP will potentially be utilised by a very wide spectrum of users. To focus the communication of information, these audiences can broadly be divided into three levels, namely political or administrative, operational and grassroots levels.

Target audiences

Following are some of the target audiences to whom the results of the NAEBP must be communicated:

Political/administrative audience

- Ministers and senior managers of relevant Departments of Central Government
- MECs of Provincial Governments
- Premiers of Provincial Governments
- Environmental Councils (National and Provincial).

Operational/managerial audience

- Directors of Departments with environmental responsibility (National and Provincial Government)
- National and Provincial Parks Boards
- Water Boards/Authorities
- Town/City Councils
- Local Authorities
- Non Governmental Organisations
- Industry.

Grassroots/interest group audience

- communities
- conservationists
- schools
- farmers
- industries
- scientists
- media.

Reporting formats

The success of the NAEBP will to a large extent be determined by the effectiveness of communicating results to the different target audiences. While raw data or index values may be sufficient for the specialists used to interpreting biological results, these formats may be meaningless to anyone who does not have an understanding of the derivation of the index, how it reflects deviation from natural/best attainable conditions, or how to correctly interpret the value of the index. For such audiences the information reflected in the index may need to be reported in simple graphical formats.

More detailed or more generalised presentations can be made of the same data, according to the preference of the target audience. The critical factor is that the source data must be reliable, and based on scientifically acceptable and standardised collection protocols. The data assessment process must also be described in sufficient detail so that different people using the same measured data will consistently arrive at the same assessment information.

Some suggestions regarding the type of information that will be needed by different audience groups, the frequency at which they will need updates and the formats which may be useful, are given in **Table 1**.

Table 1: Preliminary information specifications for the main target audiences.

Information specifications	Political level	Operational level	Grassroots level
What do they need the information for?	- auditing the state of the country's water resources - policy setting - updating legislation - budget allocation	- decision making: allocation of water; development of areas; protection of rivers and reaches - setting discharge permit conditions - identifying problem areas to focus available resources	- to be aware of the condition of rivers - to assess if authorities are managing rivers effectively
What type of information do they need?	- temporal trends in the state of health of rivers - current state relative to desired state for rivers - priority for meeting desired state - implications of meeting/not meeting desired state	- information on different ecological indicators - temporal and spatial trends - current state relative to reference state - current state relative to desired state - priority for meeting desired state - implications of meeting/not meeting desired state	- current state of health of rivers - temporal and spatial trends in the state of health of rivers
How should the information be presented?	- by area (national and provincial) - map-based, linked to iconic graphics (minimal text)	- by area: national, provincial, catchment, river reach, conservation park - map-based, linked to graphics (some numbers)	- by area: provincial, catchment, river reach, local - map-based, linked to graphics (no text) - media releases (primarily graphical plus explanatory text)
How often will they need it?	Annually	Annually	Annually

Institutional coordination

Need for wider involvement and participation

The design of the NAEBP started as a national initiative driven by DWAF's IWQS. However, neither the IWQS nor the DWAF has the regional infrastructure or resources to implement and maintain the programme on a national basis. To achieve implementation and ongoing maintenance of the NAEBP at a national scale, shared custodianship and partnerships will be required to accumulate a sufficiently large resource base to sustain the programme.

Mandates, roles and responsibilities

At a **national** level, mandates, roles and responsibilities regarding the aquatic environment are shared by three main role players, where:

- the DWAF has a mandate to monitor and manage the water resources of South Africa;
- the Department of Environmental Affairs and Tourism (DEAT) is required to produce a SOE report, in accordance with its international responsibilities, namely the 1992 Convention on Biological Diversity, Agenda 21 and the 1971 Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar);
- the Water Research Commission (WRC) is responsible for facilitating, guiding and funding water-related research in South Africa.

Furthermore, the responsibility for environmental monitoring, decision-making and management in South Africa is increasingly being devolved from national to provincial and local levels. In this regard, the main **provincial and local** role players are:

- Provincial Departments of, for example, Nature Conservation and Environmental Affairs;
- Provincial Offices of the DWAF
- National and Provincial Parks Boards
- Water Boards
- Area agencies, such as Irrigation Boards
- *Catchment Authorities* - although these water management bodies do not presently exist, the concept of catchment authorities is receiving favourable attention in current environmental policy review processes in South Africa.

Future partnerships

In line with mandates, roles and responsibilities, and considering the availability of funds, capacity and expertise, further development and implementation of the NAEBP should take place under partnership of both national and provincial stakeholders. In this partnership the national authorities will continue their initiative as custodians of the programme, while the provincial and local authorities will become operational owners of the programme at an area-specific level.

Ownership of the programme by provincial and local institutions, with the local knowledge and interests which the national custodians lack, will aid the creation of the operational infrastructures for implementing and maintaining the programme. At the same time, the active involvement and ownership of the programme by provincial and local stakeholders will ensure that these groups get the information that suits their requirements. The information generated through implementation of the NAEBP will then provide essential environmental decision-support to the resource managers with a more localised interest and responsibility.

Linking with other programmes

The knowledge gained and information generated through the development and implementation of the NAEBP can greatly benefit and supplement other programmes with an environmental focus, but with a smaller or no monitoring component. Furthermore, closer links with other programmes of national interest will assist in shaping the nature of the NAEBP, so that the public, resource managers and politicians can all gain from the future output of the programme. As a first step, because mutual benefit is likely to result from such relationships, formal collaboration with the following programmes should be investigated:

- *Working for Water Programme of the National Water Conservation Campaign*: This Programme promotes, through the clearing of invasive alien plants, the conservation of water, creation of jobs and the restoration of the natural environment. The NAEBP can assist in providing qualitative and quantitative evidence of the degree to which the Working for Water Programme improves hydrological regimes, in-stream biological conditions, river habitats and riparian integrity.

- *Kruger National Park Rivers Research Programme (KNPRRP)*: The purpose of the KNPRRP is to develop the understanding of the functioning of riverine ecosystems, and the methodologies required to define the water quality and quantity requirements of these systems. The KNPRRP and the NAEBP supplement each other directly. The NAEBP intends to collect data and generate management information, using available and practical monitoring techniques. The research approach of the KNPRRP ensures that our understanding of how to use monitoring data and indices is constantly improved and updated.

- *Consortium for Estuarine Research and Management (CERM)*

- *Monitoring River Health Initiative (MRHI) of the Australian National River Health Programme*: The thinking behind the MRHI and the NAEBP is remarkably similar, and strengthening existing links between the two initiatives can only be beneficial.

Chapter 6

Implementation Design for the NAEBP

Introduction

Introduction

This chapter deals with the last of the design phases. The implementation design phase commenced at the end of 1996. A model of wide involvement and participation has been adopted for continuing with the implementation design. Such a model will expedite and enhance the transition from designing the NAEBP to the eventual implementation of the programme.

This chapter contains the following sections:

- The implementation design phase
- Institutional arrangements
- National coordination
- Provincial implementation
- Local participation.

The implementation design phase

The next step

The phased design process which was adopted for the NAEBP has reached the stage where the conceptual design should be:

- tested through prototyping,
- modified and expanded where necessary, and
- demonstrated and evaluated for usefulness.

Furthermore, procedures and infrastructures should be developed for implementing and maintaining the programme on a national scale.

The combined result of the above steps will be the **implementation design**.

Role and nature of the implementation design phase

In essence, the implementation design should provide broad implementation guidelines which, when followed, would ensure consistency and synergy among national, provincial and local implementation activities. The implementation design, as the last step of the programme design, should address all the aspects relevant to securing the long-term maintenance of the programme. These issues include: devising functional institutional arrangements; assessing and creating the required capabilities and capacities; instituting educational and training programmes; exploring and maximising funding options; prototyping and demonstrating methods; and continuing with research and development.

The implementation design phase and the full-scale implementation and eventual operational maintenance of the NAEBP is essentially inseparable; the one naturally flows into the other and both are influenced by one another. Where the implementation design phase is the last step of the programme design process, it is also the first step of full-scale implementation (see **Figure 7**).

Figure 7

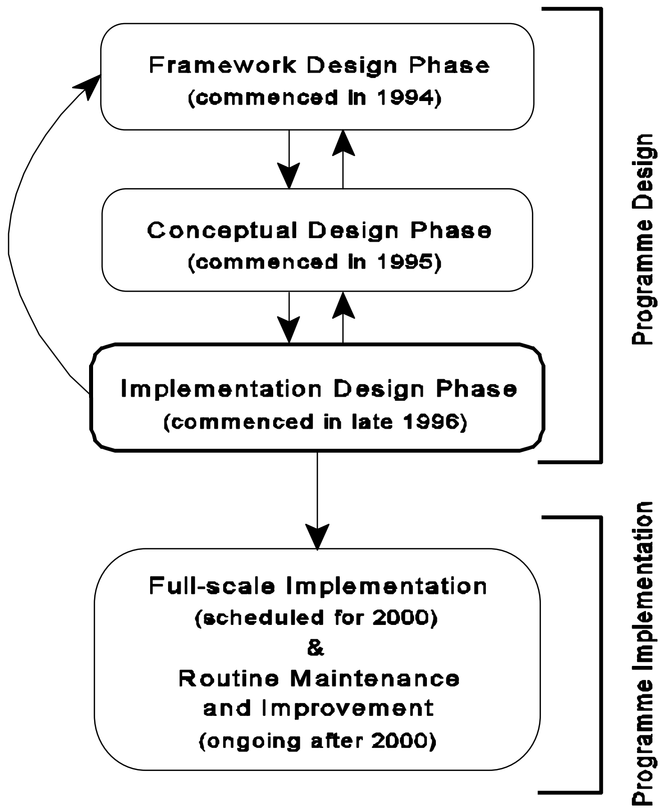


Figure 10: Chronological relationship of the implementation design phase with the rest of the design phases, as well as with the eventual implementation and maintenance of the NAEBP.

Institutional arrangements

Models for the implementation design phase

In the design process which was followed for the NAEBP, the framework design involved a limited number of people, consisting mainly of resource managers. Similarly, the conceptual design involved a limited group of people, consisting mainly of specialists.

Two broad options exist for proceeding with the implementation design phase, and hence to continue towards full-scale implementation and maintenance of the programme:

- The first option is to continue within the context of a relatively small team of experts and managers, until the scientific validity and technical detail of all programme components can be specified with a considerable amount of confidence. Such an approach will likely focus on one geographic area and produce an implementation manual which will prescribe in detail the techniques and protocols which need to be followed to implement the NAEBP in other parts of the country.

- The second option is to conduct future developments in collaboration with virtually all the groups, organisations and authorities which will ultimately be involved with, or responsible for, the implementation and maintenance of the NAEBP. This approach will spread developmental activities, in varying intensities, over the whole of the country, and will result in an operational manual shaped through the experiences and involvement of a large and diverse group of stakeholders.

Advantages and limitations of the different options

Small group option (described above):
The advantages of continuing the next phase in the context of a small project team are that this option will only require a moderate degree of coordination, it will most probably result in a product of considerable scientific standing and it will allow available funds to be focused. A limitation of this approach is that there will be a very limited degree of exposure among future political, managerial and operational stakeholders during the implementation design phase. As a result, a further transitional phase may be required before full-scale implementation, to bring relevant groups up to speed with the implementation process.

Large group option (described above):
The approach of wider collaboration will have the advantages of: fostering a natural progression from involvement in, to the implementation of, the NAEBP by all participating groups; highlighting, at an early stage, the real-world realities relevant to the implementation of a national monitoring programme; gradually creating the required capacity for each provincial region, and upgrading participation as capacity and more techniques become available; institutionalising the NAEBP - in terms of budgets, policies, priorities and workloads - at an early stage; mobilising a wider resource base and creating a richer variety of ideas. On the limiting side, the latter option will require strong coordination, as its success will largely depend on the level of support volunteered by the relevant organisations and authorities, and a limited pool of funds will have to be distributed among more participants. A further limitation of this option is that standardisation may be hampered by allowing separate developments.

In summary, the large group option will proceed more slowly in technical development, but more quickly in acceptance of the programme.

Consultation Planning Meeting

A Consultation Planning Meeting for the implementation of the NAEBP was held in September of 1996, at the CSIR Conference Centre, Pretoria. This meeting was attended by representatives from national and provincial government, conservation agencies, bodies such as water boards, and others.

Consensus on the following items were reached at the Consultation Planning Meeting:

- The NAEBP should in future be coordinated and managed under **joint custodianship** of the Department of Water Affairs and Forestry (DWAF), the Department of Environmental Affairs and Tourism (DEAT), and the Water Research Commission (WRC).

- Several provincial and local authorities and institutions are involved with some or other form of biological monitoring. These groups should **become involved and contribute** to the further development of the NAEBP.

- Existing biomonitoring activities will benefit from being **incorporated within the structured approach** of the NAEBP. While participating agencies can retain ownership of their monitoring activities and data, incorporation of these activities and data within national structures will have significant advantages in terms of standardisation of methods, availability of information, etc.

Which option for South Africa?

Through a process of consultative planning with national, provincial and local stakeholders, it became apparent that the option of wider participation is the desired way ahead towards the implementation of a biomonitoring programme in South Africa. Even at this early stage, there is sufficient support from DWAF Provincial Offices, relevant Provincial Departments, Water Boards and Parks Boards, to confidently continue with as wide an involvement as possible.

A model for institutional participation

In support of the option of wide participation, all the relevant organisations and agencies (all levels of government and private sector) must be encouraged to become active partners in the further development and testing, and owners in the eventual implementation and use of the NAEBP.

As the practical implementation and maintenance of the programme will require infrastructures at the river, catchment and provincial levels, it is proposed that the operational responsibilities, and area-specific ownership of the programme, be devolved to statutory bodies within provincial regions. The composition of a “consortium of owners” may, however, differ from province to province. A provincial NAEBP consortium of owners will also be best able to involve the many parties interested in and affected by the health of rivers in their area.

In order to optimise the coordination and maximise the resources available for implementation of the NAEBP, a model for **national coordination** (custodianship) and **provincial and local implementation** (ownership) is proposed (**Figure 8**).

Figure 8

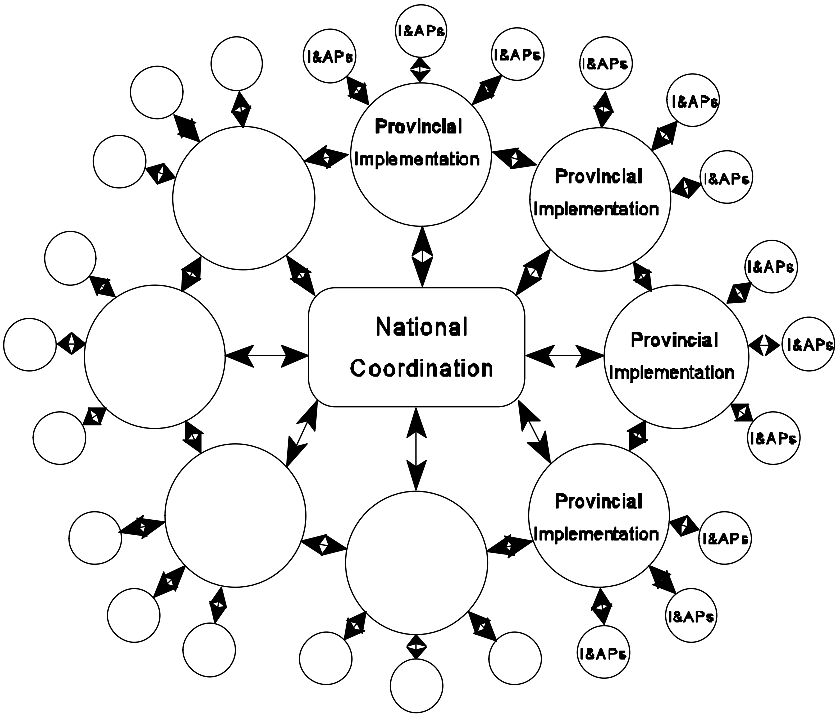


Figure 11: A model for collaborative development and implementation of the NAEBP, showing national coordination, provincial implementation and local involvement. (I&APs - Interested and Affected Parties)

National coordination

A National Coordinating Committee (NCC)

To ensure proper coordination of programme activities at a national level, the establishment of a **National Coordinating Committee (NCC)** was proposed and accepted at the Consultation Planning Meeting. The NCC will bear the responsibility of the custodianship role of the national authorities involved in the programme, and will oversee and direct all programme activities.

Responsibilities of the NCC

The main future areas of responsibility of the NCC will be as follows:

- to continue with and **coordinate the Implementation Design Phase** of the NAEBP, including the setting of guidelines and minimum requirements for provincial and local participation;
- to compile and execute **communication and marketing strategies** for different target audiences;
- to coordinate all **research and development** (R&D) regarding the NAEBP, including the development, testing and standardisation of methods and protocols and the creation of structures for the storage of data;
- to develop and implement **funding models**, specifically regarding national and international sources of funding; and
- to coordinate the availability of **training opportunities.**

Composition of the NCC

The NCC should comprise of:

- **A National Coordinator** - a full-time position, which may be filled by an employee from one of the custodian organisations or through a contract appointment
- **The Custodians** - a representative from each of the DWAF, DEAT and WRC
- **Portfolio managers** - Each of the NCC's five main areas of responsibility (see responsibilities of the NCC) should be assigned to a "portfolio manager", who will be responsible for planning, coordinating and driving developments in his/her area of activity.
- **Provincial Champions** - a representative from each provincial implementation initiative
- **Scientific advisors** - scientists who are playing leading roles in development and research related to the NAEBP, who can guide the scientific direction and act as scientific reviewers of the programme
- **Special members** - representatives from other programmes or organisations with whom mutually beneficial relationships may be formed, for example, the KNPRRP and the Working for Water Programme

---

An EXCO

An **Executive Committee (EXCO)**, which can meet frequently to discuss and decide on day-to-day programme activities, should be formed. The EXCO would comprise a quorum from the following:

- The National Coordinator
- The Custodians
- The Portfolio Managers

Decisions will be communicated to the rest of the NCC, stakeholders and I&APs through existing (e.g. the *River Health* newsletter) or additional mechanisms. This communication would be the responsibility of the Portfolio Manager on Communication and Marketing.

Provincial implementation

A Provincial Implementation Team (PIT)

A **Provincial Implementation Team (PIT)**, representing authorities and stakeholders within a particular provincial region, would be best suited to implement and own the NAEBP in that region according to the available capacity, expertise and needs within that province.

Responsibilities of the PIT

The PIT would primarily be responsible for:

- institutionalising the NAEBP within partaking institutions and organisations in the relevant geographic area, in terms of budgets, resource development priorities, policy planning, etc.;
- implementing and maintaining the NAEBP within the relevant geographic area;
- managing operational resources and infrastructures - human capacity creation, hardware, software, equipment; and
- developing and implementing funding models, specifically regarding provincial and local sources of funding.

Composition of the PIT

Ideally each PIT should function as a consortium, comprising representatives of stakeholder authorities and organisations within the relevant provincial area. The structure of the PIT should comprise the following roles:

- **A Provincial Champion -** to drive the NAEBP initiative within the provincial context, represent the PIT on the NCC and convene PIT activities; should ideally be an employee of a Provincial Department of Nature Conservation or Environmental Affairs

- **Managers and scientists** - individuals from Provincial Departments and Offices, Boards and other statutory bodies as well as industry, who will be actively involved with the provincial implementation initiative

- **Technicians and field workers** - people who will largely be responsible for the routine maintenance of the programme

- **Consultants -** to provide specialist services on a contract basis.

Local participation

Local involvement

The NAEBP renders itself ideally to involving a particularly wide and diverse group of people, from river ecologists through industrialists and farmers to grassroots communities, with an interest in river health. The relatively simple data collection techniques as well as the informative and educational nature of the resulting information, suggest the potential for active involvement of Interested and Affected Parties (I&APs).

I&APs

I&APs would liaise with the PIT of the Province within which they fall. Rivers Forums and Local Authorities are examples of mechanisms through which I&APs can consolidate their liaison with the PIT, and which would allow river- or area-specific programmes to be launched for the involvement of these groups.

Chapter 7

Strategic Issues and Action Plans

Introduction

Introduction

With organisational models in place for the further development, coordination and implementation of the NAEBP for rivers (Chapter 6), this chapter proposes a broadening of the vision for the programme. Each of the five main areas of responsibilities of the NCC are discussed in the context of a long-term programme vision. It would be a primary responsibility of the NCC to develop these strategic responsibilities further, and to integrate national, provincial and local activities in each of these areas.

The following sections are dealt with in this chapter:

- A strategic vision
- Develop and implement funding models
- Implementing the NAEBP
- Communication and marketing
- Research and development
- Training requirements.

A strategic vision

Broadening the vision

Although the development of the NAEBP has up to now focused largely on riverine ecosystems, the long-term aim is to incorporate all freshwater ecosystems in the biomonitoring programme. The organisational infrastructure which is suggested for the implementation phase of the NAEBP design (Chapter 6), provides a platform for managing an expansion of the current focus to include aspects related to the long-term aim. As such, it is timely to broaden the programme vision beyond the implementation of the current programme design to include, for example, the design of programme components for different types of aquatic ecosystems.

A vision for the future

The long-term vision of the NAEBP has been formulated as follows:

> **Implement, maintain and improve NAEBP for all inland aquatic ecosystems in South Africa and throughout the southern African region.**

Programme goals

In view of the above vision, the future goals of the programme can be formulated as follows:

Short-term (one to three years)

- Test and finalise the programme design for riverine ecosystems (recognising that the design will never truely be "final", and that it will always be updated and improved.)
- Implement and demonstrate the NAEBP for rivers, in at least three to four provinces.
- Launch projects for designing programme components for different types of freshwater ecosystems, i.e. impoundments, wetlands and lakes.
- Liaise with other southern African countries regarding their collaboration with and adoption of the NAEBP.
- Progress towards expanding the implementation of the NAEBP for riverine ecosystems across southern Africa, starting with Lesotho and Swaziland.
- Integrate all the relevant research, development and implementation activities into the framework of national coordination and provincial implementation.

Medium-term (three to six years)

- Implement and maintain, in a sustainable way, the NAEBP for all key riverine ecosystems within South Africa.
- Expand the implementation of the NAEBP for rivers to key river systems in other parts of southern Africa.
- Finalise conceptual designs and test NAEBP for impoundments, wetlands and lakes.

Long-term (more than six years and ongoing)

- Maintain and improve the NAEBP for all inland aquatic ecosystems in South Africa and throughout the southern African region.

The above goals are clearly very ambitious and should be seen as ideal goals. A regular analysis of their feasibility, in the light of future resource allocations, should be conducted to allow necessary modifications of the goals in future.

Develop and implement funding models

Areas for funding

The availability of funds is the single most important factor affecting the long-term viability of a national biomonitoring programme. Three distinct areas requiring funding can be identified, namely:

- Ongoing research and development
  - development of methods and procedures
  - testing of methods and procedures
- Implementation and operational activities
  - data collection
  - capacity creation
  - reporting
- Programme coordination
  - coordination at national and provincial levels, including liaison with I&APs and internal and external programme communication.

Resource allocation

A particular solution to a problem or challenge is rarely recognised and accepted without some demonstration of its worth. In the case of the NAEBP, small-scale demonstration of the role of biomonitoring in water resource assessment and management has led to a recognition of the usefulness of this type of monitoring. This recognition, and the acceptance of a need for the technology, resulted in the allocation of the resources (financial and human) which made the design of the programme to date possible. The conceptual design is a further demonstration of the potential worth of the programme to South Africa, which has resulted in considerable recognition of the need for, and acceptance of, the programme (e.g. the response at the Consultation Planning Meeting).

In general, the demonstration of good results from any initiative, would lead to increased support for that initiative. Effective demonstration thus has an outward spiralling effect on recognition and acceptance, resource allocation and capacity creation (**Figure 9**).

The next step for the NAEBP is to demonstrate, through pilot application in the provinces and by collecting real data, the worth of the information generated through the programme to the various users of that information. Such demonstration would, in theory, lead to increased financial support of the programme by all sectors who benefit from the information. These financial resources, from a wide spectrum of sponsoring agencies, would be essential for growing the programme towards its future vision.

Figure 9

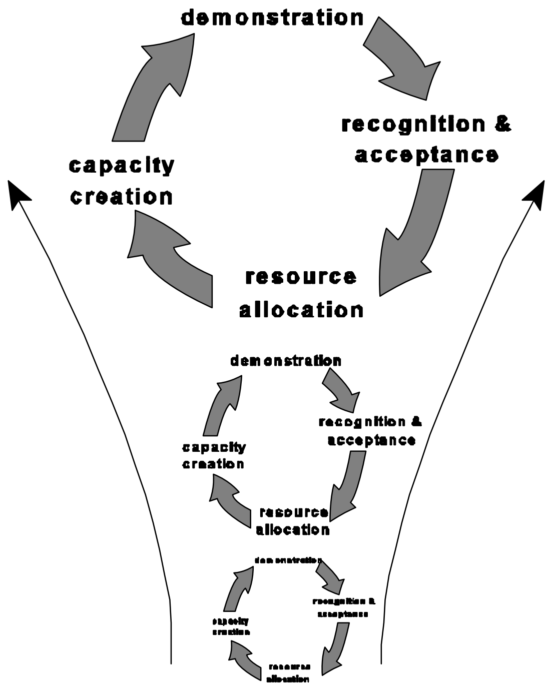


Figure 12: The demonstration versus resource allocation spiral.

Funding sources

To date the DWAF, through its IWQS, has been the primary investor in the development of the NAEBP, both in terms of committing human resources and allocating funding for associated external contracts. As the programme activities are envisaged to expand substantially, this funding will have to be supplemented. Additional support and contributions should be obtained from international, national, provincial and local (sectoral) sources:

- **International sources:** Support from international funding agencies should be sought, in particular, for expanding NAEBP activities across the southern African region.

- **National contributors:** Funding from national government and agencies should be expanded to the DEAT and WRC, as joint custodians of the NAEBP. The WRC has, in this regard, provisionally approved funding of a project on the development of provincial implementation procedures for the programme, for the period 1997 to 1999.

- **Provincial contributors:** Participating organisations at the provincial level would, at least initially, contribute largely by providing manpower and equipment.

- **Sectoral sources:** A promotional approach, for example to "adopt a river", could be instituted to attract financial support from private companies.

Who funds what?

The detail regarding funding responsibilities needs to be developed. A few ideas follow:

- Ongoing research and development may primarily be funded by the custodians.
- Multiple funding options are possible for routine maintenance of the programme, where:
  - the cost of collecting data from reference sites may be borne by central government;
  - provincial or local bodies, or Parks Boards and Water Boards, may find it advantageous to maintain monitoring at sites strategic to them;
  - the cost of monitoring at impacted monitoring sites may be borne by individuals or organisations responsible for creating the specific environmental problem to be monitored.
- The funding of coordinating activities may be shared among sponsors, where requirements for specific functions or portfolios can be made explicit.

Time frames

For the **short term** (next three years), sufficient funding must be secured to ensure proper programme coordination, to test and verify the NAEBP for riverine ecosystems, and for initiating provincial implementation initiatives. Additionally, some funding would be required to continue with research and development, and to expand the NAEBP to other types of ecosystems and other countries. In terms of direct funding, a minimum of approximately R1,5 million per anum, for the next three years, will be required to continue with the implementation vision of the monitoring programme.

Over the **medium term** (three to six years), sufficient funding will need to be generated for the implementation and maintenance of the NAEBP for riverine ecosystems in South Africa and some additional parts of southern Africa, as well as for the design and testing of programme components for impounded, wetland and lake ecosystems.

The **long-term** (more than six years and ongoing) funding requirements would be for the maintenance and ongoing improvement of the entire NAEBP, throughout the southern African region.

Implementing the NAEBP

Need for coordination

As provincial implementation projects will be initiated, the need for coordination of national and provincial activities will increase. Although duplication of effort should be avoided, the tolerance of separate prototyping initiatives, with different research and development focuses, will probably benefit the programme in the long term. Multiple prototyping and implementation initiatives will automatically result in wide participation, and in a range of new ideas, views and suggestions.

The NCC will provide the forum for debating and attaining consensus on which procedures and protocols to adopt for the NAEBP. This forum will ensure standardisation within the national programme and the transfer of knowledge among provincial and local participants.

National Workshop

Although the NCC is envisaged to meet approximately three to four times per year, these meetings will not be suitable forums for presenting, discussing and making decisions regarding progress at both national and provincial levels. It is, therefore, recommended that an annual National Workshop be instituted, where managers, scientists, industrialists, conservationists and other can present their activities related to the NAEBP, and where relevant topics can be workshopped in detail. Such a workshop would probably need to be at least two to three days in duration.

Provincial activities

Where coordination at all levels is primarily a national responsibility, implementation and maintenance of the programme is primarily a provincial responsibility. Ideally, a consortium of Provincial Departments and Offices, other catchment or park-related organisations, as well as local stakeholders, will become the "owners" of the programme in their area. In order to successfully implement, maintain and update the NAEBP in their area, the Provincial Implementation Team (PIT) needs to:

- be aware of developments nationwide (through their representation on the NCC);
- communicate their activities internally and externally of the provincial boundaries;
- attain support from the appropriate managerial, administrative and political role players;
- create and maintain sufficient capacity by suitably developing their organisations and training their people;
- develop the policies which would enable and ensure the use of the information forthcoming from the programme, to the benefit of the people of the province.

Management actions

The development of the NAEBP is a direct result of a management information need. Therefore, the programme must feed information to decision-makers, and this information must ultimately result in a higher efficiency in environmental decision-making. This implies that the programme will have a deciding effect on actions taken regarding the management of river ecosystems.

As the national programme is not intended to provide detailed information, for example on the specific causes of ecological impairment, it will highlight areas of unacceptable impact. Resources can then be focused and more detailed investigations can be carried out at the problem areas. This more detailed and more frequent monitoring can be integrated with the national monitoring programme, to provide answers to specific questions and hence direct the management of the aquatic resource (**Figure 10**).

Figure 10

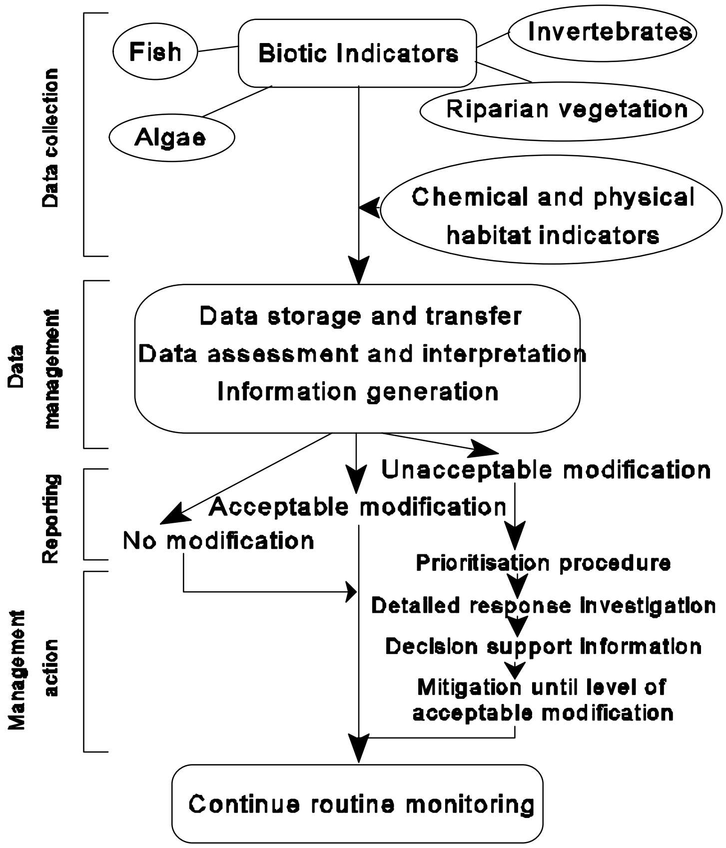


Figure 13: Flow diagram indicating the different routine components of a monitoring programme and how the results of the programme may influence management actions.

Communication and marketing

A strategy

A primary requirement for successful communication regarding and marketing of the NAEBP, is the compilation of a detailed communication and marketing strategy. Such a strategy would propose action plans, for the short- and long-term, for all target audiences. Some of the components of the strategy would be:

- a direct communication campaign,
- an information campaign,
- media liaison and publicity, and
- educational programmes.

Direct communication campaign

A direct communication campaign would include both internal communication (among those involved in the programme) and external communication (to those not directly involved with the programme). Internal communication would include meetings, such as that of the NCC and an annual National Workshop and liaison within and between provinces. External communication would include presentations at conferences and road shows focusing, for example, on local communities, industrialists or government officials.

Information campaign

An information campaign would focus on distributing information on the programme. The main media for achieving this would be via printed material, such as the publication of a programme newsletter (the first edition of *River Health* was published in late 1996), pamphlets focusing on the programme or interesting programme components and posters showing how biomonitoring is conducted or reflecting some of the results from biomonitoring. The production of a video on the programme is a further option.

Media liaison and publicity

Media liaison would be an important component of the information campaign and would include the handling of the following:

- press releases,
- media briefings,
- interviews on television and radio,
- press conferences, and
- media enquiries.

Educational programmes

Educational programmes would serve a dual purpose in that it would expose and raise the awareness of people regarding the programme as well as assist in the creation of capacity. In this regard, adult learning centres, local communities, river forums, schools and government departments are all possible forums for launching educational programmes.

Research and development

Further development

Research and development for the NAEBP can be divided into activities related to providing new tools and protocols, and activities related to improving or updating existing tools and protocols. Information requirements are constantly evolving; similarly, monitoring programmes always need to reflect the latest understanding and availability of technology. Research and development are, therefore, ongoing activities, to provide information constantly which is relevant and will make a difference in terms of decision-taking.

Testing and verification

Once developed in concept, methods and protocols need to be tested and verified before they can finally be incorporated into the NAEBP. In the short term, testing of the protocols proposed for the NAEBP for riverine ecosystems need to take place.

Integration

Methods and protocols, which have been developed and verified, must be integrated to form a coherent unit in the operational monitoring programme. Although the different programme components are often developed separately, the links between these components will ultimately determine the degree of synergy between them. As an example, the data assessment techniques must provide the types of information to which managers will react. The same data must be readily accessible from data storage facilities, and these storage structures must be programmed so that the relevant biological data can be captured with reasonable ease. The data collection techniques must, furthermore, ensure that the relevant biological data are collected in a systematic and standardised way.

Standardisation

Methods and protocols which are intended for routine application, should be documented in user manuals. Such manuals can be updated, and would provide all the guidelines necessary to implement and maintain the NAEBP.

Auditing and quality control

Mechanisms need to be put in place to ensure that proposed protocols and methods are used as intended, and that the resulting data are satisfactorily quality approved.

Training requirements

Training needs

It is not advisable for the NAEBP to start its own training programme, but rather to make use of existing facilities and communicate its training needs to training organisations, such as Technicons.

Training needs can be classified into the following categories:

- training managers in the use of biological information, which would typically take the form of a short course,
- training technicians in the techniques and expertise needed to conduct the biosurveys, or to capture and manage the data,
- training scientists in disciplines of taxonomy, ecology, etc., which are relevant to the ongoing development and improvement of the NAEBP.

Competence-based training needs

The viability of competence-based (as opposed to semester-based) courses, where technicians can be trained until they are competent as “biomonitors”, should be investigated. Practical experience should be an essential component of training. Field experience could be gained at various organisations around the country.

Chapter 8

Conclusion

In essence, biomonitoring is a scientific procedure, which can be used to provide resource information. The principal role of this monitoring information is to drive and direct the processes of decision making and management. These processes include:

- assessing information and identifying problems;
- crafting regional and national policies, regulations and eventually legislation;
- establishing criteria, standards and management objectives for combatting deteriorating environmental conditions; and
- demonstrating results in the environment.

In broad terms, the NAEBP has to contribute to science-based management of aquatic ecosystems, in support of national, provincial and local mandates to manage the water resources of South Africa. If the nation's rivers (and estuaries, seas and impoundments) are maintained at an appropriate level of ecological integrity, then the efforts of resource managers would have been successful.

The NAEBP provides a structured framework for incorporating aquatic biomonitoring techniques into the assessment and management of water resources. A critical factor for the long-term success of this monitoring programme is sufficient support from national authorities to allow proper testing and implementation of the relevant protocols. Once implemented, the programme should be maintained by provincial and local authorities who require the information to properly manage the water resources in their area of responsibility.

The information generated by the NAEBP will assist in locating those areas where water resource managers have been successful and those areas where they need to focus their attention. Through the monitoring of structural and functional attributes of ecosystems, the NAEBP will also provide an information base for managing the chemical, physical and biological processes that shape ecological integrity.

Appendix A

Sources of Information and further reading

Other documents in this series

C Hohls, D.R. 1996. National Biomonitoring Programme for Riverine Ecosystems: Framework document for the programme. NBP Report Series No 1. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

C Brown, C.A., Eekhout, S. & King, J.M. 1996. National Biomonitoring Programme for Riverine Ecosystems: Proceedings of spatial framework workshop. NBP Report Series No 2. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

C Eekhout, S., Brown, C.A. & King, J.M. 1996. National Biomonitoring Programme for Riverine Ecosystems: Technical considerations and protocol for the selection of reference and monitoring sites. NBP Report Series No 3. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

C Uys, M.C., Goetsch, P-A. & O'Keeffe, J.H. 1996. National Biomonitoring Programme for Riverine Ecosystems: Ecological indicators, a review and recommendations. NBP Report Series No 4. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

C Department of Water Affairs and Forestry. 1996. National Biomonitoring Programme for Riverine Ecosystems: Proceedings of consultation planning meeting. NBP Report Series No 5. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

Scientific articles

C Armitage, P.D., Moss, D., Wright, J.F. & Furse, M.T. 1983. The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. *Water Research*. **17**: 333-347.

C Cairns, J. (Jr). 1990. The genesis of biomonitoring in aquatic ecosystems. *The Environmental Professional*. **12**: 169-176.

C Cairns, J. (Jr). 1995. Ecological integrity of aquatic systems. *Regulated Rivers: Research and Management*. **11**: 313-323.

C Cairns, J. (Jr), McCormick, P.V. & Niederlehner, B.R. 1993. A proposed framework for developing indicators of ecosystem health. *Hydrobiologia*. 263: 1-44.

C Cocklin, C., Parker, S. & Hay, J. 1992. Notes on the cumulative environmental change I: Concepts and issues. *Journal of Environmental Management*. **35**: 31-49.

C Herricks, E.E. & Cairns, J. (Jr). 1982. Biological monitoring: Part III - Receiving system methodology based on community structure. *Water Research*. **16**: 141-153.

C Jackson, S. & Davis, W. 1994. Meeting the goal of biological integrity in water-resource programs in the US Environmental Protection Agency. *Journal of the North American Benthological Society*. **13**: 592-597.

C Karr, J.R. & Dudley, D.R. 1981. Ecological perspectives on water quality goals. *Environmental Management*. **5**: 55-68.

C Kleynhans, C.J. 1996. A qualitative procedure for the assessment of the habitat integrity status of the Levuvhu River (Limpopo System, South Africa). *Journal of Aquatic Ecosystem Health*. **5**: 1-14.

C Minns, C.K. 1995. Approaches to assessing and managing cumulative ecosystem change, with the Bay of Quinte as a case study: an essay. *Journal of Aquatic Ecosystem Health*. **4**: 1-24.

C Munkittrick, K.R. & McCarty, L.S. 1995. An integrated approach to aquatic ecosystem health: top-down, bottom-up or middle-out? *Journal of Aquatic Ecosystem Health*. **4**: 77-90.

C Nip, M.I. & De Haes, H.A.U. 1995. Ecosystem approaches to environmental quality assessment. *Environmental Management*. **19**: 135-145.

C Oberdorff, T. & Hughes, R.M. 1992. Modification of an index of biotic integrity based on fish assemblages to characterise rivers of the Seine Basin, France. *Hydrobiologia*. **228**: 117-130.

C Reynolds, C.S. 1993. The ecosystem approach to water management. The main features of the ecosystem concept. *Journal of Aquatic Ecosystem Health*. **2**: 3-8.

C Roux, D.J., Van Vliet, H.R.& Van Veelen, M. 1993. Towards integrated water quality monitoring: Assessment of ecosystem health. *Water SA*. **19**: 275-280.

C Steedman, R.J. 1994. Ecosystem health as a management goal. *Journal of the North American Benthological Society*. **13**: 605-610.

C Stevens, D.L. (Jr). 1994. Implementation of a National Monitoring Program. *Journal of Environmental Management*. **42**: 1-29.

C Suter II, G.W. 1990. Endpoints for regional ecological risk assessments. *Environmental Management*. **14**: 9-23.

C Vallentyne, J.R. 1993. Biospheric foundations of the ecosystem approach to environmental management. *Journal of Aquatic Ecosystem Health*. **2**: 9-13.

C Wright, J.F., Furse, M.T. & Armitage, P.D. 1993. RIVPACS - a technique for evaluating the biological quality of rivers in the U.K. *European Water Pollution Control*. **3**: 15-25.

C Yoder, C.O. 1994. Towards improved collaboration among local, State, and Federal agencies engaged in monitoring and assessment. *Journal of the North American Benthological Society*. **13**: 391-398.

Books

C Moss, B. 1995. *Ecology of Fresh Waters - Man and Medium*. Second Edition. Blackwell Science Ltd., London.

C Odum, E.P. 1971. *Fundamentals of Ecology*. Third Edition. W.B. Saunders Co. London.

C Woodley, S., Kay, J. & Francis, G. (eds). *Ecological Integrity and the Management of*

Ecosystems. St. Lucie Press.

Other reports and documents

- Breen, C., Quinn, N. & Deacon, A. 1994. *A Description of the Kruger Park Rivers Research Programme (Second Phase)*. Foundation for Research Development, Pretoria, South Africa.
- DEAT. 1996. *An Environmental Policy for South Africa*. Green paper for public discussion. Department of Environmental Affairs and Tourism, Pretoria, South Africa.
- DEAT. 1996. *Green Paper on the Conservation and Sustainable Use of South Africa's Biological Diversity*. Department of Environmental Affairs and Tourism, Pretoria, South Africa.
- DWAF. 1991. *Water Quality Management Policies and Strategies in the RSA.* Department of Water Affairs and Forestry, Pretoria, South Africa.
- DWAF. 1994. *Water Supply and Sanitation Policy: Water - an Indivisible Asset*. White Paper of the Department of Water Affairs and Forestry, Pretoria, South Africa.
- DWAF. 1995. A National Biomonitoring Programme - assessing the health of aquatic ecosystems. Information brochure published by the Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.
- DWAF. 1995. *Procedures to Assess Effluent Discharge Impacts.* Department of Water Affairs and Forestry, Pretoria, South Africa.
- DWAF. 1996. *Water Law Principles - Discussion Document*. Department of Water Affairs and Forestry, Pretoria, South Africa.
- Karr, J.R., Fausch, K.D., Angermeier, P.L., Yant, P.R. & Schlosser, I.J. 1986. Assessing biological integrity in running waters - a method and its rationale. Illinois Natural History Survey, Special Publication 5. Champaign, Illinois.
- King, J.M. 1995. Enquiries regarding a national biomonitoring initiative, made during a trip to Australia in June - July 1995. Unpublished Southern Waters' report to the Institute for

Water Quality Studies, Department of Water Affairs and Forestry.

C Thornton, K.W., Saul, G.E. & Hyatt, D.E. 1994. Environmental Monitoring and Assessment Program Assessment Framework. Report No. EPA/620/R-94/016. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

C Uys, M.C. 1994. Classification of Rivers and Environmental Health Indicators. Proceedings of a joint South African/Australian workshop. February 7-14 1994, Cape Town, South Africa. Water Research Commission Report No. TT 63/94.

Appendix B

Contact Names

Custodian representatives

Organisation	Name	Contact Numbers	
Department of Water Affairs and Forestry	Dr Henk van Vliet	(012) 808-0374 (012) 808-0338 eea@dwaf-hri.pwv.gov.za	tel fax e-mail
Department of Environmental Affair and Tourism	Mr Geoff Cowan	(012) 310-3701 (012) 322-2682 nat_geof@ozone.pwv.gov.za	tel fax e-mail
Water Research Commission	Dr Steve Mitchell	(012) 330-0340 (012) 331-2565 steve@wrc.ccwr.ac.za	tel fax e-mail

Provincial Champions

Province	Name	Contact Numbers	
Northern	Mr Mick Angliss	(0158) 22369	tel
		(0158) 22369	fax
Mpumalanga	Dr Johan Engelbrecht	(01323) 2395	tel
		(01323) 2732	fax
North-West	Prof Braam Pieterse	(0148) 299-2500	tel
		(0148) 299-2503	fax
Gauteng	Ms Candice Rickard	(012) 201-2041	tel
		(012) 201-3380	fax
Kwazulu/Natal	Dr Chris Dickens	(0331) 341-1151	tel
		(0331) 341-1084	fax
Northern Cape and Free State	Mr Maitland Seaman	(051) 401-2863	tel
		(051) 448-8711	fax
	Mr Pierre de Villiers	(051) 861-1371	tel
		(051) 861-2089	fax
Eastern Cape	Mr Nicholas Scarr	(041) 33-8891	tel
		(041) 33-7755	fax
Western Cape	Dr Barbara Gale	(021) 887-0111	tel
		(021) 887-1606	fax
	Dr Kas Hamman	(021) 483-4232	tel
		(021) 23-0939	fax

Appendix C

Glossary of Terms

Aquatic biomonitoring is the long-term gathering of biological information in both the laboratory and the field for the purpose of making some sort of environmental assessment.

Aquatic ecosystems are ecosystems which provide a medium for habitation by aquatic organisms and sustain aquatic ecological processes.

An **assessment end-point** is the result of an interpretation (assessment) of measured data, often in conjunction with other related data. In the context of aquatic biomonitoring, this assessment should provide some measure or index of environmental conditions relative to a baseline state, other aquatic systems, or the same system at other times. It will not necessarily explain the causes of any change in condition.

A **biological index** is used to quantify the condition of an ecosystem by integrating and summarising biological data within a particular biological indicator group.

Biological indicator - see **Ecological indicators**

Ecological indicators are characteristics of the environment, both biotic and abiotic, that can provide quantitative information on the condition of ecological resources.

Ecological integrity refers to 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 characteristics of ecosystems within a specific region. (In simpler terms, ecological integrity implies that the structure and functions of an ecosystem are unimpaired by anthropogenic (human-induced) stresses.)

An **ecosystem** is any unit that includes all of the organisms (i.e. the community) in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycles (i.e. exchange of material between living and non-living parts) within the system.

Ecosystem health can be defined as a value judgement of the overall condition (health) of an ecosystem based on the social well-being, economic development and ecological integrity within that system.

Indicator - see **Ecological indicators**

A **measurement end-point** is the result of an actual measurement of some ecological response to a stressor(s).

Monitoring sites are sites which are identified as important in assessing the condition of a river, for example, a site selected on a river reach known or thought to be experiencing an impact on water quality or habitat degradation.

Reference condition refers to a benchmark of the best attainable ecological conditions for a specific type of river.

A **reference site** is a relatively unimpacted site that can be used to define the best physical habitat, water quality and biological parameters for a specific type of river.

A **stressor** is any physical, chemical or biological entity or process that can induce adverse effects on individuals, populations, communities or ecosystems

Appendix D

Glossary of Abbreviations/acronyms

BP1-5	Biomonitoring Protocol 1 to 5
CCI	Channel Classification Index
DEAT	Department of Environmental Affairs and Tourism
DWAF	Department of Water Affairs and Forestry
EMAP	Environmental Monitoring and Assessment Programme (of the United States)
EXCO	Executive Committee
FCI	Fish Community Index
GI	Geomorphological Index
HAM	Habitat Assessment Matrix
HBDI	Hydraulic Biotope Diversity Index
HI	Hydrological Index
I&AP	Interested and Affected Party
IHI	Index of Habitat Integrity
IWQS	Institute for Water Quality Studies
KNPRRP	Kruger National Park Rivers Research Programme
MEC	Member of the Executive Committee

NCC	National Coordinating Committee
NAEBP	National Aquatic Ecosystem Biomonitoring Programme
PIT	Provincial Implementation Team
R&D	Research and Development
RVI	Riparian Vegetation Index
SASS4	South African Scoring System version 4
SOE	State of the Environment
RIVPACS	River Invertebrate Prediction and Classification (British biomonitoring methodology)
WQI	Water Quality Index
WRC	Water Research Commission

Appendix E

List of Figures

Appendix F

List of Tables

Table No. | **Title** | **Page**