



C.A.P.E. ESTUARIES PROGRAMME

Monitoring Programmes for Implementation in South African Estuaries

G.6

C.A.P.E. Estuarine Management Guideline



Version 1
September 2007

Our strategic vision for the estuaries in the Cape Floristic Region is:

*Our estuaries are beautiful, rich in plants
and animals, they attract visitors,
sustain our livelihoods and
uplift our spirits.*

*C.A.P.E. Estuaries Guidelines 6: Monitoring programmes for implementation in
South African estuaries*

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Monitoring

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1. Introduction

The development of a Generic Estuarine Management Plan for the Cape Floral Region (CFR) project (a component within the larger C.A.P.E. Estuaries Programme) included the development of a series of guideline documents to assist in the development of estuarine management plans, specifically aimed at local management level. One aspect that had to be addressed was guidance on the development and implementation of long-term monitoring programmes in estuaries of the CFR.

Protocols for monitoring have been developed as part of various other studies, such as the Reserve Determination process (DWAF, 2004), Eastern Cape Estuaries Management Programme Monitoring Protocols (McGynne & Adams, 2004) and proposed refinements to monitoring protocols for application in the Reserve determination process (Taljaard, Van Niekerk, Huizinga & Joubert, 2003). For the purpose of this study, these existing protocols were reviewed to provide guidance in the development and implementation of long-term monitoring programmes in the CFR.

Ultimately, the monitoring protocols proposed here should be expanded into an Estuarine Health Monitoring Programme for the region – and ultimately for the country (similar to the River Health Programme). The development of an Estuarine Health Monitoring Programme for the CFR will be dealt with as a separate project.

Sustainable management of estuaries can only be achieved through appropriate and reliable quantitative data. However, the collection, processing and interpretation of such data are often time-consuming and costly, and often require considerable scientific expertise. Presently there is no generally accepted protocol to guide South African authorities in the design and implementation of estuary monitoring programmes. Consequently, monitoring is project specific and discontinuous, plays little part in guiding management decisions and is retarded by a lack of integration between responsible authorities and programmes. This absence in alignment between management requirements and existing monitoring programmes and activities in South African estuaries was also highlighted at the National Estuaries Workshop held in Port Elizabeth in May 2000 (Boyd *et al.*, 2000).

It is important to note the difference between baseline measurement programmes and long-term monitoring programmes, in the context of the proposed generic framework for the development and implementation of Estuarine Management Plans (EMPs) (Figure 1):

- Baseline measurement programmes (or surveys) usually refer to shorter-term or once-off, intensive investigations of a wide range of parameters to obtain a better understanding of ecosystem (estuarine) functioning (usually part of Situation Assessment and Evaluation and the Objective-Setting Phase).
- Long-term monitoring programmes refer to ongoing data-collection programmes that are done to evaluate continuously the effectiveness of management strategies/actions designed to maintain a desired environmental state so that responses to potentially negative impacts, including cumulative effects, can be implemented in good time (usually fits into the *Monitoring* component).

The emphasis here is mainly on the latter.

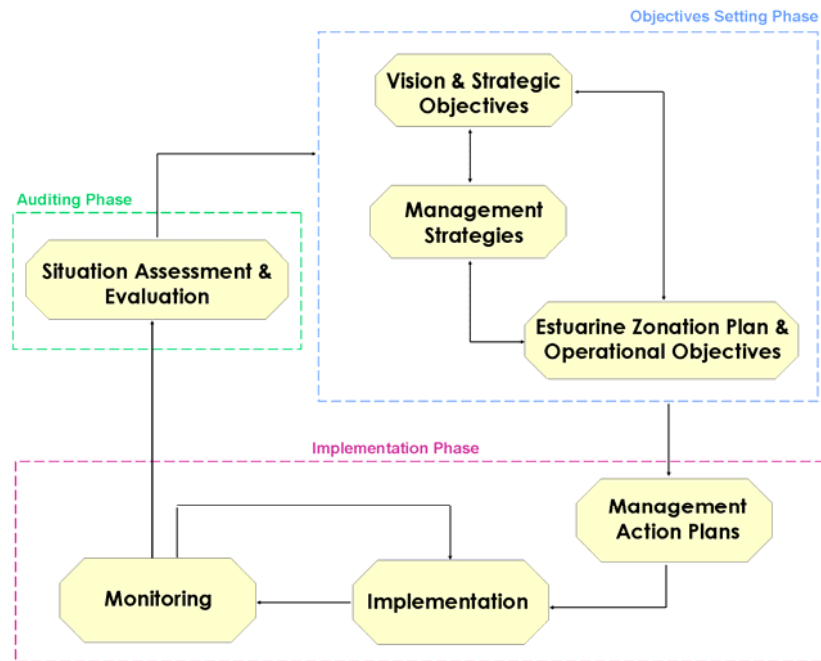


Figure 1. *Proposed generic framework for the development and implementation of Estuarine Management Plans*

Although baseline measurement programmes and long-term monitoring programmes have different purposes, it is extremely important that long-term monitoring programmes follow on from similarly structured baseline studies. In essence, the monitoring activities selected for the long-term monitoring programme should be distilled from the measurement programmes conducted as part of the baseline studies, but usually on less intensive spatial and/or temporal scales.

2. Key Elements of a Successful Monitoring Programme

Site-specific monitoring programmes for individual estuaries are largely determined by the type of activities and developments, as well as the site-specific physical, biogeochemical and ecological characteristics of the system and the variability thereof.

Considering that one of the key objectives of a long-term monitoring programme is to evaluate the effectiveness of management strategies/actions designed to maintain a desired environmental state, it is critical that long-term monitoring programmes consider the outcomes of other components within the EMP, in particular:

- Situation Assessment and Evaluation;
- Estuarine Zonation Plan and Operational Objectives; and
- Management Action Plans.

Without taking these aspects into consideration, the danger exists that a long-term monitoring programme will become monitoring for the sake of monitoring rather than fulfil the crucial role of informing, and subsequently providing a means of adapting and improving estuarine management programmes.

Although the design of long-term monitoring programmes should be a dynamic, iterative process to be adjusted continuously to incorporate new knowledge, thereby supporting the principle of adaptive management, there are key elements to a successful monitoring programme (ANZECC, 2000; US-EPA, 2003) (Figure 2), namely:

- Definition of monitoring objectives;
- Selection of appropriate monitoring parameters (indicators);
- Refinement of spatial and temporal scales;
- Appropriate sampling and analytical techniques; and
- Appropriate reporting techniques.

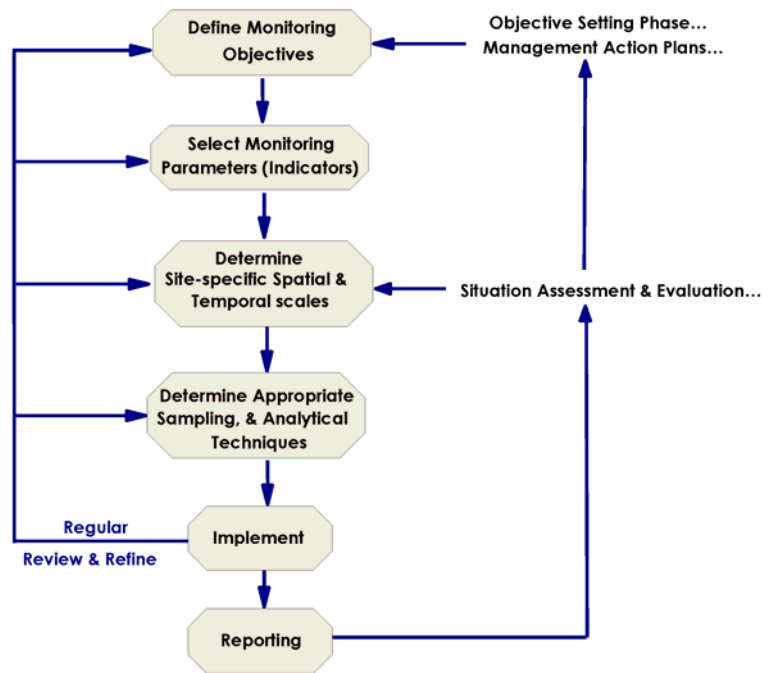


Figure 2. Key aspects to be addressed as part of long-term monitoring programmes

2.1 Setting of Monitoring Objectives

Measurable, site-specific monitoring objectives are key components of a sound long-term monitoring programme. Such clear objectives make it possible to design a focused and cost-effective monitoring programme. Usually, monitoring objectives are derived from the operational objectives and management action plans which, in turn, are based on the vision for and strategic objectives of a particular estuary.

Monitoring objectives can take on many forms. For example, they can be translated into hypotheses that could be proved statistically. Another approach, used in the Ecological Water Requirement Methodology of the Department of Water Affairs and Forestry (DWAF) (under the National Water Act (No. 36 of 1998) (NWA), is the concept of 'Thresholds of Potential Concern' (TPC) (Rogers & Biggs, 1999). TPCs are defined as measurable end-points related to specific indicators that, if reached, prompts management intervention. TPC endpoints should be defined such that they provide early warning signals of potential non-compliance to operational objectives (i.e. not the point of 'no return'). This concept also implies that the indicators selected for inclusion in long-term monitoring programmes need to include ecological, social and/or economic parameters that are particularly sensitive to changes associated with specific activities and development characteristics of a particular estuary.

TPCs also serve as the link between the process of management and the hypothesis-testing approach of science. Institutional and societal goals, on the other hand, are less rigorously defined and are more difficult to pinpoint and implement, since they involve the management of complex human structures and processes. They do, however, provide targets that can assist planning and provide direction for management (McGwynne & Adams, 2004).

In South Africa, long-term ecological data on estuaries that would assist the identification of TPCs are often lacking, incomplete, outdated or inaccessible. In addition there is a poor understanding of the status of living resource stocks as well as many uncertainties related to the consequences of human activities such as speed boating, disturbance of birds, trampling on supratidal marshes and the ecological isolation of estuaries caused by development. In the absence of recognised guidelines or standards, TPCs are often set arbitrarily and independently. To accommodate these grey areas, TPC specifications can be allocated according to available conservation information and social criteria and formulated as hypotheses to test their validity (McGwynne & Adams, 2004; Turpie, Adams, Joubert, Harrison, Colloty, Maree, Whitfield, Wooldridge, Lamberth, Taljaard & Van Niekerk, 2002; Kleynhans, 2003).

Choosing TPCs should form part of a broad consultative process that integrates the value systems of stakeholders with management objectives. Continuous validation through testing the hypotheses on which TPCs are based keeps management adaptive to new knowledge and understanding of systems function (McGwynne & Adams, 2004; Rogers & Biggs, 1999).

2.2 Selection of indicators

The selection of indicators (or monitoring parameters) is usually site specific and should be able to quantify whether monitoring objectives (as defined above) are being complied with. Key determining factors in the selection of monitoring parameters are, for example:

- Type of activities and developments within an estuary; and
- Anticipated impacts on the health of aquatic ecosystems and other goods and services provided by the estuary.

Indicators that should typically be included in any long-term monitoring programmes for estuaries – as these provide essential information required to interpret changes in higher trophic levels – include:

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- River inflow (i.e. flow gauging);
- Continuous water-level recording at the estuary mouth (recording the state of the mouth – a key driver for most biotic components);
- Water quality of river inflow;
- Water quality and flow rate of effluent discharges into estuaries; and
- Salinity distribution patterns under different river-flow ranges.

Aerial photographs, collected on an annual basis, are also considered a very useful monitoring parameter to be included in the long-term monitoring of estuaries, as these provide useful information on both abiotic and biotic components.

The inclusion of other abiotic indicators such as sediment characterisation, bathymetric and topographical surveys, water quality (other than salinity) in the estuary and accumulation of toxic substances in sediments will depend on the type of activities and developments in the area, the sensitivity of a particular system to changes in such indicators, as well as the level of interaction of such indicators with the selected biotic indicators. Another consideration for inclusion would be any particular abiotic indicator that is on a 'trajectory of change'.

Suitable indicators in ecosystems with high natural variability, such as estuaries, may require high resolution sampling frequency to be effective, often with high cost implications. It is therefore usually more appropriate (and cost effective) to select indicators associated with ecological components that tend to integrate or accumulate impacts or change over time, such as sediment and biota. However, there are instances where indicators associated with more dynamic ecological components (e.g. the water column) are most appropriate, such as using microbiological indicators (e.g. *Enterococci* or *E. coli*) to monitor human health risks in recreational or marine aquaculture waters.

Monitoring of estuarine biota can be done by means of measuring different parameters, including species diversity, relative abundance, and community structure and composition. As it is often very expensive to conduct detailed biological monitoring programmes that measure entire biotic communities, indicator species are often selected as proxies for evaluating ecosystem health. Where an estuary supports biotic species of economic importance, for which operational objectives can be set quite easily, the distribution and abundance of these species are also effective indicators in long-term monitoring programmes. Criteria that should be considered in the selection and prioritisation of biotic indicators for long-term monitoring programmes include the following:

- Biotic components that are on a 'trajectory of change' or that are particularly sensitive to activities and developments within the estuary that are on a 'trajectory of change'.
- Biotic components that are of regional or national biodiversity importance, particularly when these are also sensitive to impacts from activities and developments in a particular estuary. For example, the bird population of the Berg River Estuary, being a Ramsar site, is of high biodiversity importance and should therefore be included as a parameter in the long-term monitoring programme of that estuary. The biodiversity importance of most South African estuaries has been rated in a document prepared by Turpie *et al.* (2002) and can be used in this regard.

- Biotic indicators should also be representative of the important food chains present in a particular system. This will ensure that monitoring programmes provide resource managers with appropriate data to establish 'cause and effect' links, a key requirement for effective management of estuaries. For example, in the Breede River Estuary, fish was identified as being of high importance; therefore the main food source of the most important fish species, namely the macro-crustaceans (swimming prawn) should also be included, as should the macrophytes (*Phragmites*), being an important habitat for the swimming prawns.
- The selection of biotic indicators should also present a balance between indicators that provide 'early warning' signals and those that reflect longer-term, more cumulative effects. For example, fish is often considered to be useful 'early warning' indicators, while macrophyte distribution patterns are often better indicators of cumulative, longer-term changes in estuaries.

It is therefore important that scientifically sound reasons are provided for the selection of specific indicators in a particular study area. Before choosing a particular indicator as a monitoring parameter of ecosystem health, it is important to also test it against the following criteria (McGwynne & Adams, 2004; ANZECC, 2000):

- Is sensitive to potential impacts;
- Response will reflect the overall ecological condition or integrity of the estuary;
- Approaches to sampling and data analysis can be highly standardised;
- Response can be measured rapidly, cheaply and reliably;
- Response has some diagnostic value;
- Provides a representative view of environmental (biophysical, social and institutional) conditions and pressures, and societal responses;
- Is reliable and robust yet sensitive enough to provide an early warning of unacceptable change;
- Is scientifically credible;
- Is simple, cost effective, easy to understand and practicable;
- Shows trends over time;
- Provides a basis for local, regional and national comparisons;
- Has a threshold or limit of acceptable change that can serve as an end-point; and
- Has relevance to policy and management needs.

A useful checklist that can be used to assist in the selection of suitable indicators, in general, is provided in Table 1 (ANZECC, 2000).

Table 1. Checklist for selection of measurement parameters (from ANZECC, 2000)

Relevance	<i>Does the measurement parameter reflect directly on the issue of concern?</i>
Validity	<i>Does the measurement parameter respond to changes in the environment and have some explanatory power?</i>
Diagnostic value	<i>The measurement parameter must be able to detect changes and trends in conditions for the specified period. Can the amount of change be assessed quantitatively or qualitatively?</i>
Responsiveness	<i>Does the measurement parameter detect changes early enough to permit a management response, and will it reflect changes due to the manipulation by management?</i>
Reliability	<i>Is the measurement parameter measurable in a reliable, reproducible and cost-effective way?</i>
Appropriateness	<i>Is the measurement parameter appropriate for the time and spatial scales that need to be resolved?</i>

2.3 Refinement of spatial and temporal scales

Setting spatial boundaries for a monitoring programme is important, because inappropriate boundaries might focus efforts away from driving or consequential factors (ANZECC, 2000). The anticipated influence of anthropogenic activities and developments therefore needs to be taken into account in the specification of the spatial boundaries of a long-term monitoring programme. Sampling locations can also be dictated by the location of designated beneficial use areas within an estuary. For example, recreational areas or marine aquaculture farms will be logical sampling locations within estuaries.

The temporal scale of a monitoring programme (i.e. sampling frequency) largely depends on the:

- Variability in the load of contaminants from marine pollution sources;
- Variability in processes driving transport and fate in the receiving environment; and
- Temporal sensitivity of the ecosystem to pollutant loading, i.e. exposure time versus negative impact.

Sampling frequency should at least resolve the main source of natural variability of the indicator under investigation. Scales of change over time differ widely in the water column (minutes – days) compared, for example, with sediment or biota (days – seasons – decades). Non-periodic events, such as storms, can also have a dramatic influence that needs to be taken into account where appropriate. A sampling frequency that is too low relative to the underlying natural variability will result in biased data that will make it difficult to separate a human-derived impact from a natural anomaly. In the same way, sampling at a frequency that is too low relative to the variability of a specific activity or development (e.g. sewage effluent discharge) may result in marked negative impacts being missed. For example, in order to resolve the problem of the variability in the water column, sampling frequencies generally have to be high (e.g. hourly – daily – weekly). As a result, the use of water column indicators, as part of monitoring programmes, can become very expensive.

Traditionally, long-term monitoring programmes included intensive sampling grids to overcome the inherent uncertainties of the spatial (and temporal) variability of a system. However, with the use of numerical modelling, many of the inherent problems of the traditional approach can be overcome. Predictive (numerical) modelling has proven to be very useful in enhancing the design of long-term monitoring programmes and improving the interpretation of the results of monitoring. Such numerical models provide the process links that enhance the ability to diagnose problem areas, as well as anticipate problems through their predictive capacity. The benefits of numerical modelling in the spatial and temporal design of long-term monitoring programmes include:

- Definition of the most critical space- and time-scales of impact in the system: Important insights are provided by the combination of the synthesis of the existing understanding of the key processes and the model assumptions and inputs; and
- Improved interpretation and understanding of the monitoring results in the context of a dynamic environment.

Although long-term monitoring programmes may, initially, still require relatively intensive spatial (and temporal) scales to address uncertainties in a system's response, over a number of years, these can be reduced to only a few selected points through an iterative process, as the predicted responses of the system are verified.

2.4 Sampling and analytical techniques

The choice of sampling and analytical techniques to apply in a monitoring programme is largely dependent on the selection of indicators and the output that is required to properly evaluate whether monitoring objectives are complied with.

Key requirements that need to be stipulated in a sampling programme include:

- Sampling technique;
- Number of replicates (determined by the statistical technique used in analysis); and
- Sample handling and storage.

For long-term comparisons, it is critical that analytical procedures applied in the analysis of chemical and biological samples be subject to proper calibration, and preferably also within an established national or international inter-calibration programme – to ensure legally defensible results that are comparable between different laboratories and institutions.

A major concern here is the use of incorrectly or non-calibrated *in situ* instrumentation to record biogeochemical indicators, such as temperature, salinity, pH, dissolved oxygen and turbidity in estuaries. Such instrumentation always provides results, of which the accuracy is solely dependent on proper calibration. Problems are typically encountered where such instrumentation are used by persons that are not qualified or trained in its proper use and calibration.

2.5 Reporting

In the evaluation of monitoring data, the following are important aspects that need to be considered:

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- **Data qualification.** The required accuracy and precision of data need to be clearly defined before embarking on data acquisition exercises. Rounding-off and the number of significant figures must be defined for each type of data. A high level of confidence with regard to data accuracy is essential for any further analysis.
- **Appropriate (statistical) techniques.** Computers and statistical software are valuable tools for the evaluation of environmental data. However, they are only tools: The ultimate assessment depends on scientific expertise, as well as a proper understanding of statistical procedures and their applicability to environmental data. Where statistical expertise is limited, commercially available software packages (or the techniques described in the following section) must be used cautiously. Statistical techniques that are applied inappropriately can result in erroneous results or interpretations.

To be useful from a management perspective, it is crucial that monitoring results be reported in a clear format to provide the appropriate scientific knowledge for informed and effective decision making.

Often the most effective manner in which to communicate environmental data and information is through graphical presentation, in that large data sets can be illustrated effectively. Graphical presentation is also effective in showing qualitative aspects (such as correlations and trends) and quantitative aspects (such as outliers). It is also a user-friendly means of communicating complex numerical and statistical outputs.

The frequency of reporting is also important. For example, compliance monitoring (e.g. monitoring of composition and volumes of effluent discharges) requires near 'real-time' (i.e. as close as possible to the time of sampling) reporting to ensure that mitigating measures are implemented timeously. Sediment or biological monitoring programmes may require less frequent reporting, e.g. usually six-monthly or annually.

In general, a Monitoring Report needs to include:

- A list of monitoring objectives and how these relate to the objectives within the EMP for the estuary;
- Details of the design and implementation of the monitoring programme (also indicating the relationship between selected indicators and monitoring objectives);
- An evaluation of the monitoring data in relation to the monitoring objectives. This evaluation should make use of data summaries and graphical presentations in order to enhance readability;
- A statement on whether the monitoring objectives have been met;
- In the event of non-compliance, possible reasons for the non-compliance;
- Recommendations on management strategies and actions that could be taken to address non-compliance;
- Recommendations on refinements to the monitoring programme; and
- Appendices containing laboratory reports, raw data tables and other relevant background information.

Monitoring data is expensive to collect and require substantial investments of both human and financial resources. As a result, such data must be made as usable, useful and retrievable as possible. The sheer volume of data generated as part of ongoing monitoring programmes dictates that computer-based data management systems must provide the basis for data storage and management. A good data management system should have (ANZECC, 2000):

- Reliable procedures for the recording of analytical and field observations;
- Procedures for systematic screening and validation of data (quality control);
- Secure storage of information;
- A simple retrieval system;
- Simple means of analysing data; and
- Flexibility to accommodate additional information.

3. Existing Monitoring Protocols for Estuaries

Protocols for monitoring that are currently being used in South African estuaries include those proposed for application in the Ecological Water Requirement Studies on Estuaries (DWAF, 2004; Taljaard *et al.*, 2003) and the Eastern Cape Estuaries Management Programme Monitoring Protocols (McGwynne & Adams, 2004).

A brief summary of these protocols are provided below.

Existing monitoring protocols for estuaries (as discussed below) can best be refined/adapted for estuaries in the CFR through the series of case studies planned in a as part of the larger C.A.P.E. Estuaries Programme.

It is therefore proposed that the monitoring protocols for the Determination of Ecological Water Requirement for Estuaries (DWAF, 2004; Taljaard *et al.*, 2003 as summarised in Chapter 3.1) and the monitoring protocols of the Eastern Cape Management Programme (McGwynne & Adams, 2004, as summarised in Chapter 3.2) be consulted in the development of the site-specific monitoring programmes for each of the case study estuaries.

The outcome of these studies can then be used to refine guidelines for the development and implantation of monitoring programmes in the estuaries of the CFR.

3.1 Method for Determination of Ecological Water Requirements for Estuaries

The *Methods for the Determination of the Ecological Water Requirements for Estuaries, Version 2* (DWAF, 2004) is currently the only requirement (or protocol) for baseline measurement programmes. The purpose of these programmes is to collect data and information to characterise and understand the ecosystem functioning of a specific system so as to be able to determine Resource Directed Measures such as the reference condition, Present Ecological State, Ecological Importance, Ecological Reserve Category and Resource Quality Objectives (RQO). In 2003, a group of estuarine specialists undertook a Water Research Commission study wherein refinements to these protocols for baseline measurement programmes as well as protocols for long-term monitoring programmes were proposed. The purpose of these protocols is to assess (or audit) whether

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RQOs are being complied with. In addition, long-term monitoring programmes can also be used to improve and refine the Ecological Reserve and associated RQOs.

These procedures or protocols distinguish between the different levels at which these studies can be under taken, namely at Intermediate or Comprehensive level.

Here the generic procedures for long-term monitoring programmes provide guidelines for each abiotic and biotic component in terms of sampling procedures, spatial scales and temporal scales, should these be selected as indicators for long-term monitoring. In most instances the sampling procedures and spatial scales remain the same as for the baseline studies, but the temporal scales are usually less intense, i.e. long-term monitoring programmes are essentially a 'scaled down' version of the baseline studies.

Initially, long-term monitoring programmes may have to include an extended list of abiotic and biotic indicators, but as the understanding of system response improves, the list of indicators, as well as spatial and temporal scales could be reduced. The scaling down of long-term monitoring programmes should be conducted by qualified estuarine specialists and needs to be accompanied by sound scientific motivation. It is important that long-term monitoring programmes are not scaled down prematurely as it can impact on effective management of estuaries, for example:

- Premature elimination of indicators or reduction of spatial and temporal scales could result in the lack of crucial information required to back-track changes to the actual cause, i.e. understanding of important 'cause and effect' chains, particularly those linked to changes in river inflow and water quality.
- Long-term monitoring programmes also need to capture variability caused by long-term dry/wet cycles before scaling down, as the response of the system under these long-term climatic cycles can be vastly different which, if not understood and documented properly, can lead to incorrect management decisions.

To accommodate the high variability in the biophysical functioning of estuaries, the approach in setting procedures for the resource monitoring programmes (as part of the Ecological Reserve Determination process) is to provide generic sampling procedures (including recommended spatial and temporal scales) for each abiotic and biotic component, to be applied when a component is selected for inclusion in either baseline studies or the long-term monitoring programme of a particular estuary.

Therefore, although the estuarine specialist team appointed on a particular Ecological Reserve Determination study will have some flexibility in customising the resources monitoring programme to meet site-specific requirements, this approach will ensure uniformity in the manner in which field data is collected in estuaries as part of the Ecological Reserve determination and implementation process.

Abiotic and biotic components included in methods for the determination of Ecological Water Requirements for estuaries are (DWAF, 2004):

- Hydrology;
- Sediment dynamics;
- Hydrodynamics;

- Water quality;
- Microalgae;
- Macrophytes;
- Invertebrates (including zooplankton, benthic invertebrates and macrocrustaceans);
- Fish (ichthyofauna); and
- Birds (avifauna).

The revised procedures for baseline measurement studies and proposed procedures for long-term monitoring programmes for application in Ecological Water Requirement studies, as proposed by Taljaard *et al.* (2003), are summarised below. In most instances the sampling procedures and recommendations on spatial scales remain the same for baseline studies and long-term monitoring programmes. However, there is a distinction in the recommended temporal scale between:

- Baseline studies for Ecological Reserve Determination (Intermediate level);
- Baseline studies for Ecological Reserve Determination (Comprehensive level); and
- Long-term monitoring programmes.

Table 2. Procedures for baseline measurement and long-term monitoring programmes for application in Ecological Water Requirement studies (Taljaard *et al.*, 2003)

SAMPLING PROCEDURE	Description of the sampling (and analytical) procedures that need to be followed for a particular abiotic or biotic component.	
SPATIAL SCALE	Recommendation on the manner in which spatial scales (i.e. sampling stations) need to be selected for a particular abiotic or biotic component.	
TEMPORAL SCALE	INTERMEDIATE LEVEL	COMPREHENSIVE LEVEL
	Recommended frequency of sampling for an Ecological Reserve Determination at Intermediate level.	Recommended frequency of sampling for an Ecological Reserve Determination at Comprehensive level.
	LONG-TERM MONITORING PROGRAMME (where selected as indicator)	
	Recommended frequency of sampling of a component selected as an indicator for a long-term monitoring programme.	

Hydrology:

SAMPLING PROCEDURE	<i>Simulated run-off data: Data to be simulated for reference condition, present state and a range of future run-off scenarios covering a range of flow reductions from present to worst case.</i>	
	<i>Flood hydrographs: To be simulated for the 1:1 to 1:200 year floods for reference condition, present state and a range of future run-off scenarios (usually only required on comprehensive level).</i>	
SPATIAL SCALE	<i>Simulated river run-off: Representative of inflow at head of estuary.</i>	
	<i>Flood hydrographs: Representative of flow at head of estuary.</i>	
	INTERMEDIATE LEVEL	COMPREHENSIVE LEVEL
TEMPORAL SCALE	<i>Simulated river run-off: Simulated over a 50- to 80-year period, provided as average monthly flows (daily flows may at times be required).</i>	<i>Simulated river run-off: Similar to intermediate level reserve.</i>
	<i>Flood hydrographs: Usually not required for intermediate level reserve.</i>	<i>Flood hydrographs: Provided as hourly flows over the flood period.</i>
	LONG-TERM MONITORING PROGRAMME	
	<i>Not relevant.</i>	

Sediment dynamics:

SAMPLING PROCEDURE	<i>Sediment grabs: Grab samples should be collected using a Van Veen or a Zabalocki-type Eckman grab (to characterise recent sediment movement) for particle size analyses.</i>
	<i>Sediment cores: Core samples should be collected using a corer (for historical sediment characterisation).</i>
	<i>Bathymetric/topographical surveys: Surveys should be conducted using D-GPS and echo-sounding to monitor berm height, mouth sediment dynamics and cross-section profiles upstream of the mouth.</i>
	<i>Sediment load at head of estuary (including detritus component – particulate carbon/loss on ignition).</i>
SPATIAL SCALE	<i>Sediment grab samples: Along entire estuary at 500 to 1 000 m intervals.</i>
	<i>Sediment cores: Intervals similar to cross-section profiles (see below) where considered appropriate by sediment specialist.</i>
	<i>Bathymetric/topographical surveys: Mouth region – intensive (10 to 50 m interval depending on the size of the estuary and variability in bathymetry); upstream cross-section profiles along entire estuary at 500 m to 1 000 m intervals.</i>
	<i>Sediment load at head of estuary.</i>

	<i>INTERMEDIATE LEVEL</i>	<i>COMPREHENSIVE LEVEL</i>
TEMPORAL SCALE	<i>Sediment grabs, sediment cores, bathymetric/topographical surveys and sediment load at head of estuary: Available data, usually these measurements are not required as part of intermediate level reserve.</i>	<p><i>Sediment grabs: Seasonal sampling (spring, summer, autumn and winter) for one year.</i></p> <p><i>Sediment cores: Once-off.</i></p> <p><i>Bathymetric/topographical surveys: Will depend on the time scale of dominant sedimentation/erosion processes in an estuary varying between one- and five-year intervals, with a minimum record of about 15 years. Alternatively, numerical models can be used to simulate longer-term processes.</i></p> <p><i>Sediment load at head of estuary: Daily for a minimum of five years.</i></p>
TEMPORAL SCALE	LONG-TERM MONITORING PROGRAMME (where selected as indicator)	
	<i>Bathymetric/topographical surveys and grab samples.</i>	<i>Every three to six years, depending on the time scale of dominant sedimentation/erosion processes in an estuary, as well as after flood events.</i>
	<i>Sediment loads.</i>	<i>Daily records.</i>
IMPORTANT NOTES: SEDIMENT DYNAMICS		

- *Suitable sediment data records cannot be acquired in the short term. Therefore, if sediment processes in estuaries are to be better understood and quantified, long-term programmes will have to be implemented. In this regard it is recommended that DWAF implement such monitoring activities timeously in South African estuaries, particularly those earmarked for substantial water abstraction in future.*
- *The disturbance of the sediment erosion/deposition equilibrium in an estuary can lead either to siltation, resulting in the estuary becoming shallower, or to the erosion of important sediment habitats. Under natural conditions many estuaries were probably in a state of long-term equilibrium of sedimentation and erosion. However, this equilibrium can be disturbed because of changes in run-off, especially if the occurrences and magnitudes of major floods are changed.*
- *Floods and, in some cases, high seasonal flows can influence the sediment erosion/deposition equilibrium. Floods can alter important features within an estuary, such as the bathymetry (e.g. channel depth or the size of intertidal areas) and sediment composition (e.g. sand or mud).*

Hydrodynamics:

MONITORING ACTION	<i>Continuous flow recording of river inflow: A flow-gauging station should be installed to measure river inflow.</i>
	<i>Continuous water level recordings: A continuous water-level recorder should be installed at the mouth of the estuary.</i>
	<i>Daily observations: Where possible, daily mouth observations should be logged in temporarily open/closed estuaries and particularly in systems with the semi-closed mouth phase. The time at which the observation was made and the state of the tide must also be recorded, ideally at low tide.</i>
	<i>Water levels along estuary: Where a reserve determination study requires</i>

	<p>numerical modelling, water levels recordings must also be collected along the length of the estuary, either using continuous water-level recorders or water-level gauging poles and manual observations.</p> <p>Wave conditions: Available data should be accessed, but no measurements are specified as part of a baseline monitoring programme.</p> <p>Aerial photographs: Full colour geo-referenced rectified aerial photographs 1:5 000 scale covering the entire estuary based on the geographical boundary at low tide in summer, i.e. similar to those for macrophyte surveys. Must include the breaker zone near the mouth.</p>	
SPATIAL SCALE	<p>Continuous flow gauging: Head of estuary.</p> <p>Continuous water-level recording: Mouth area.</p> <p>Mouth observations: Mouth.</p> <p>Water levels along estuary: Two to six stations along estuary.</p> <p>Aerial photographs: Entire estuary, particularly the mouth area.</p>	
TEMPORAL SCALE	INTERMEDIATE LEVEL	COMPREHENSIVE LEVEL
	<p>Continuous flow gauging: Minimum of five years depending on mouth closure.</p> <p>Water-level recordings and mouth observations: Minimum of five years depending on mouth closure.</p> <p>Water levels along estuary: Manually/digitally recorded over one spring tidal cycle and one neap tidal cycle or continuous recordings over two weeks.</p> <p>Wave conditions: Available data.</p> <p>Aerial photographs: Available data.</p>	<p>Continuous flow gauging: 5–15 years depending on mouth closure.</p> <p>Water level recordings at mouth and mouth observations: 5–15 years depending on mouth closure.</p> <p>Water levels along estuary: Similar to intermediate level reserve.</p> <p>Wave conditions: Similar to intermediate level reserve.</p> <p>Aerial photographs: Available data, but needs to include one recent photograph representative of present condition.)</p>
	LONG-TERM MONITORING PROGRAMME	
	Continuous flow recording of river inflow.	Continuous
	Continuous water level recordings at mouth.	Continuous
	Aerial photos.	Annually
IMPORTANT NOTES: HYDRODYNAMICS		

- In requesting continuous flow, the request is not for gauging weirs to be constructed at the top of each estuary as such, but rather that flows be monitored in appropriate ways that will not disturb migration of aquatic biota.
- Continuous flow recordings (gauging station) of river inflow at the head of estuaries and continuous water-level recording at estuary mouths (and mouth observations) require longer-term data sets and it is therefore necessary to start such baseline monitoring programmes well in advance (at least five years) of a ecological reserve determination study. In this regard it is recommended that DWAF implement such monitoring activities timeously in South African estuaries, particularly those earmarked for substantial water abstraction in future.

Water and sediment quality:

SAMPLING PROCEDURE	<i>Water quality of river inflow: System variables (pH, DO, turbidity, suspended solids, TDS and temperature), nutrients (inorganic nitrogen [nitrite, nitrate and ammonia], reactive phosphate and silicate) and toxic substances (where relevant) should be measured.</i>
	<i>Water quality of the near-shore marine waters: Obtained from available literature.</i>
	<i>Water quality in estuary: The following samples should be collected:</i> <ul style="list-style-type: none"> ▪ <i>Salinity and temperature profiles (also required for hydrodynamics)</i> ▪ <i>System variables (pH, DO, turbidity, suspended solids)</i> ▪ <i>Inorganic nutrients (nitrate/nitrite, ammonia, reactive phosphate and reactive silicate).</i>
	<i>Salinity and temperature data must be collected at 0,5 m depth intervals, while other water quality parameters are collected in surface and bottom waters. At stations deeper than 10 m, a sample at an intermediate depth may also be required (site-specific decision).</i>
	<i>Effluent discharges: Where effluent discharges occur into the estuary, i.e. beyond the head of the estuary, these have to be sampled as well. In addition to flow rate, other parameters to be monitored will depend on the composition of the effluent.</i>
SPATIAL SCALE	<i>Toxic substances: Where relevant (e.g. in estuaries receiving run-off from urban and industrial areas and contaminated agricultural run-off), sediment samples should be collected and analysed for toxic substances (i.e. trace metals, petroleum hydrocarbons, herbicides and pesticides). To assist with the interpretation of results, samples should also be analysed for sediment grain size distribution and organic content.</i>
	<i>A sampling station is defined as a location at a specific 'distance from the mouth' that can be sampled at different depth intervals and is defined by GPS positioning data.</i>
	<i>Water quality of river inflow: Head of estuary.</i>
	<i>Water quality in estuary: Small estuaries (< 5 km long) – Stations distributed geographically along the entire estuary with a minimum of five sites. Ensure that all the salinity regimes are covered.</i>
	<i>Larger estuaries (> 5 km long) – Stations distributed geographically along the entire estuary at fixed intervals. A rough estimate for setting the distance between stations is to divide the length of the estuary by 10 (i.e. if an estuary is 30 km long, the distance between stations should be about 3 km). Typically a representative number of stations for longer estuaries are between 10 and 15. Ensure that all the salinity regimes are covered.</i>
<i>In systems with large cross-sectional areas, sampling stations should also be selected along cross sections. During each sampling survey, water quality samples must also be taken in the river and in the near-shore marine waters (i.e. the water sources).</i>	
<i>Effluent discharges: At end of pipe just before entering the estuary.</i>	
<i>Toxic substances: A grid of sediment sampling stations to be selected across the estuary, specifically targeting depositional areas (characterised by finer sediment grain sizes and/or higher organic content).</i>	

TEMPORAL SCALE	INTERMEDIATE LEVEL	COMPREHENSIVE LEVEL
	<p><i>Water quality of river inflow: At least monthly, minimum of five-year data record.</i></p> <p><i>Water quality in estuaries: Once during a low flow and a high flow season. For temporarily open/closed systems, a stable closed phase must be sampled as well as a stable open phase.</i></p> <p><i>Sampling should coincide with microalgae surveys and the invertebrate surveys in year 1.</i></p> <p><i>Effluent discharges: Should be licensed under the National Water Act where operators are required to monitor effluent volume and composition. Spatial scale, e.g. daily or weekly, will depend on the variability in effluent composition overtime.</i></p> <p><i>Toxic substances: Once, preferably during the low flow season.</i></p>	<p><i>Water quality of river inflow: At least monthly, minimum of 5- to 15-year data record.</i></p> <p><i>Water quality in estuary: Similar to intermediate level reserve except that sampling should be conducted seasonally, (i.e. during spring, summer, autumn and winter) with river inflow being representative of a particular season.</i></p> <p><i>In systems where the semi-closed phase or overwash is important, these states need to be sampled. These phases are dynamic and require three subsurveys.</i></p> <p><i>Sampling should coincide with the microalgae surveys and invertebrate surveys in year 1.</i></p> <p><i>Effluent discharges: Similar to intermediate level reserve.</i></p> <p><i>Toxic substances: Similar to intermediate level reserve.</i></p>
LONG-TERM MONITORING PROGRAMME (where selected as indicator)		
	<i>River inflow.</i>	<i>At least monthly.</i>
	<i>Effluent discharges.</i>	<i>Should be licensed under the National Water Act where operators are required to monitor effluent volume and composition. Spatial scale, e.g. daily or weekly, will depend on the variability in effluent composition overtime.</i>
	<i>Water quality in estuary.</i>	<i>Samples to be collected when related biological sampling surveys (requiring water quality data for interpretation) are conducted.</i>
	<i>Sediment surveys of toxic substances.</i>	<i>Once every three to six years.</i>

IMPORTANT NOTES: WATER QUALITY

- *The analytical techniques used in the processing of marine and estuarine water quality samples vary greatly from those used in the analysis of fresh water samples. It is therefore crucial that the analyses of water quality samples be conducted by an accredited marine analytical laboratory.*
- *Estuaries receive water from two sources, i.e. the river and sea, each with distinctively different water quality characteristics, particularly in terms of system variables and nutrients. In turn, the water quality characteristics along the length of an estuary depend on the extent of the influences of each of these sources (governed by hydrodynamic processes), as well as biochemical processes (e.g. organic degradation, eutrophication) taking place at that point within the estuary. The influence of biochemical processes is particularly evident in parts of an estuary where residence time of water becomes longer, often observed along the middle reaches of an estuary during the low flow season. It is therefore also crucial that water samples in the two sources, i.e. river and sea.*
- *River water quality requires longer-term data sets and it is therefore necessary to start such baseline monitoring programmes well in advance (at least five years). For example, monitoring points at the head of estuaries could be included in the water quality monitoring programme of DWAF.*
- *At present water quality of near-shore waters is not measured on a routine basis along the South African coast, as is the case for some rivers. Because the seawater quality may show strong seasonal variability, particularly along the West Coast, a short-term monitoring survey may not necessarily be representative. In the short term, data on near-shore seawater quality therefore needs to be derived from available data sources, including the South African Water Quality Guidelines for Coastal Marine Waters. Volume 1: Natural Environment (DWAF, 1995), until such time as routine water quality monitoring programmes are implemented along the South African coast.*
- *For toxic substances (e.g. trace metals and hydrocarbons) it is considered more appropriate to sample environmental components that tend to integrate or accumulate change over time, such as sediments. However, these surveys need not be done in ALL estuaries, only in systems where river water quality or human activities along the banks of the estuary suggest possible contamination (e.g. industrial effluents or storm water run-off from large urban developments).*
- *For long-term monitoring programmes, water and sediment quality data are particularly important for interpretation of specific biological responses and must therefore be collected by the relevant biotic components as indicated during their sampling surveys.*
- *Malfunctioning septic tanks, situated in close proximity to the banks of estuaries, may have an influence on water quality in the estuary. However, unlike point-source discharges, e.g. effluents from wastewater treatment works, it is often difficult to quantify the inputs from such diffuse sources. Even so, where septic tanks are known to be a problem or potential problem in a particular estuary, inputs need to be taken into account in the water quality assessments.*

Microalgae:

SAMPLING PROCEDURE	<i>Phytoplankton: To estimate phytoplankton biomass, collect duplicate samples for chlorophyll a at the surface and 0,5 m depth intervals. Use a spectrophotometer for sample analysis before and after acidification. Do cell counts (at 400 x magnification) on dominant phytoplankton species to establish species distribution and composition, i.e. green algae, flagellates, dinoflagellates, diatoms and blue-green algae.</i>
	<i>Benthic microalgae: Collect intertidal and subtidal benthic samples for chlorophyll a (biomass) analysis. Collect five samples at each station. Analyse samples using a recognised technique, e.g. HPLC. Record the relative abundance of dominant algal groups, i.e. green algae, dinoflagellates, diatoms and blue-green algae and identify the dominant species.</i>

	<p>At each station also measure:</p> <ul style="list-style-type: none"> ▪ Water salinity and inorganic nutrients ▪ Sediment particle size distribution and organic content ▪ Light penetration (PAR or Secchi disk). 	
SPATIAL SCALE	<p>A sampling station is defined as a location at a specific 'distance from the mouth' that can be sampled at different depth intervals (e.g. in the case of phytoplankton).</p> <p>As a guideline, the number of stations in a small estuary (< 5 km long) should not be less than five, distributed along the entire length of the estuary, covering the different salinity zones.</p> <p>For larger estuaries (> 5 km long), 10 to 15 stations selected geographically along the entire length of the estuary, covering the different salinity zones, can be used as the guideline. Stations should preferably be set at fixed intervals. A rough estimate for setting the distance between stations is to divide the length of the estuary by 10 (i.e. if an estuary is 30 km long, the distance between stations should be about 3 km).</p> <p>Salinity zones in estuaries typically include:</p> <ul style="list-style-type: none"> ▪ Fresh (representative of river) ▪ 0–10 ppt ▪ 10–20 ppt ▪ 20–35 ppt 	
TEMPORAL SCALE	INTERMEDIATE LEVEL	COMPREHENSIVE LEVEL
	<p>Once during a low flow and a high flow season. For temporarily open/closed systems, a stable closed phase must be sampled as well as a stable open phase.</p> <p>Sampling should also coincide with the water quality survey and the invertebrate surveys in year 1.</p>	<p>Similar to intermediate level reserve except that sampling should be conducted seasonally, (i.e. during spring, summer, autumn and winter) for two years with river inflow being representative of a particular season.</p> <p>In systems where the semi-closed phase or overwash is important, these states need to be sampled. These phases are dynamic and would need to be sampled on three occasions.</p> <p>Sampling should coincide with the water quality survey and the invertebrate surveys in year 1.</p>
	LONG-TERM MONITORING PROGRAMME (where selected as indicator)	
	<p>Phytoplankton (water column).</p>	<p>Two years after implementation conduct a summer and winter survey followed by a summer and winter survey every three years thereafter.</p>
<p>Benthic microalgae.</p>	<p>Two years after implementation conduct a summer and winter survey followed by a summer and winter survey every three years thereafter.</p>	

IMPORTANT NOTES: MICROALGAE

- *Water measurements (salinity, temperature, other physico-chemical properties and inorganic nutrients) need to be collected during the microalgae surveys. Combining water and sediment quality surveys on a particular estuary with the microalgae survey does this most cost effectively.*
- *The temporal scale of the microalgae sampling needs to match that of the invertebrates (zooplankton) to link the response patterns of these biotic components as best as possible.*

Macrophytes:

**SAMPLING
PROCEDURE**

The following information needs to be captured from recent and any available historical aerial photographs and orthophotographs covering the entire estuary as defined by the geographical boundaries:

- *Number of different habitats (plant community types)*
- *Area covered by each plant habitat*
- *Historical change in area covered by plant habitat*
- *Extent of anthropogenic impacts (agriculture, flood plain development).*

Field data need to be collected for ground truthing of aerial photographs:

- *Number of different plant habitats (plant community types)*
- *Area covered by each plant habitat*
- *Species list for each plant habitat*
- *Extent of anthropogenic impacts such as grazing, trampling, alien vegetation, boating, bait digging.*

Permanent transects (sampling stations) need to be set up for long-term monitoring of changes in plant habitats:

- *Transects set up along an elevation gradient*
- *Record percentage cover of each plant species in duplicate quadrates (1 m²) along transects.*

Along each transect (minimum of four) the following data need to be collected:

- *Elevation profile and water level*
- *Water column salinity and turbidity*
- *Sediment salinity, moisture content and sediment composition.*

In large supratidal salt marsh areas, boreholes are required to measure depth to water table and ground-water salinity.

SPATIAL SCALE	A sampling station is defined as a transect across the estuary (at a specific 'distance from the mouth'), with a number of quadrates arranged along the transect.	
	Aerial photos: The entire estuary needs to be covered, as defined by the geographical boundaries.	
	Transects and quadrates: As a guide the larger estuarine plant habitats in a system (e.g. salt marsh) representative of the lower (two transects) and middle (two transects) reaches should be covered. Other plant habitats, particularly those sensitive to changes in freshwater inflow, could also be monitored.	
TEMPORAL SCALE	INTERMEDIATE LEVEL	COMPREHENSIVE LEVEL
	Once-off survey during summer. For temporarily open/closed systems, preferably during the open phase.	For permanently open systems, once during high flow and once during low flow. For temporarily open/closed estuaries, one survey needs to be conducted in a stable closed phase and one in a stable open phase.
	LONG-TERM MONITORING PROGRAMME (where selected as indicator)	
	Aerial photos, transects and quadrates.	Two years after implementation conduct a summer survey, followed by a summer survey every three years thereafter (where aerial photographs are available for intermediate years these should also be analysed). Temporarily open/closed system preferably sampled in stable open phase.
IMPORTANT NOTES: MACROPHYTES		

- There are nine different habitat types recognised for estuaries,* namely:

HABITAT TYPE	INDICATOR SPECIES
Open surface water area	Indicates available habitat for phytoplankton
Intertidal sand and mudflats	Indicates available habitat for intertidal benthic microalgae
Submerged macrophyte beds	<i>Zostera capensis</i> (eelgrass), <i>Ruppia cirrhosa</i> , <i>Potamogeton pectinatus</i>
Macroalgae	<i>Cladophora</i> spp., <i>Enteromorpha</i> spp., <i>Caulerpa filiformis</i>
Intertidal salt marsh	<i>Spartina maritima</i> , <i>Sarcocornia perennis</i> , <i>Triglochin</i> spp,
Supratidal salt marsh	<i>Sarcocornia pillansii</i> , <i>Sporobolus virginicus</i>
Reeds and sedges	<i>Phragmites australis</i> , <i>Schoenoplectus littoralis</i>
Mangroves	<i>Avicennia marina</i> , <i>Rhizophora mucronata</i> , <i>Bruguiera gymnorrhiza</i>
Swamp forest	<i>Barringtonia racemosa</i> , <i>Hibiscus tiliaceus</i>

- *These include the microalgal habitats as the area covered by each habitat is used to calculate the overall botanical importance of an estuary.

Invertebrates:

<p>SAMPLING PROCEDURE</p>	<p><i>Zooplankton: Collect quantitative samples using a flow meter <u>after dark</u>, preferably during neap tides (mid to high tide) because currents are less strong and zooplankton will be more active in water column. Sampling to be done at mid-water level, i.e. not surface.</i></p> <p><i>Two net trawls (WP 2–200 micron mesh), giving replicates (i.e. two samples) at each station. The net should be pulled for three minutes per station (10–12 m³ of water) at 0,15 knots diagonally across the estuary.</i></p> <p><i>Record species and abundance (density per volume) in each trawl and average results for station.</i></p> <p><i>At each station phytoplankton samples (i.e. water column sample) and benthic microalgae samples need to be collected for chlorophyll a analyses.</i></p>
	<p><i>Benthic invertebrates: Collect (subtidal) samples using a Zabalocki-type Eckman grab sampler with five to nine randomly placed grabs (replicates) at each station. Collect intertidal samples at spring low tide using a core sampler of minimum 150 mm diameter and 250 mm depth, with five replicates at each site along the transect. Put one grab/core sample in a bucket and fill with in situ water. Add a drop of formalin and stir vigorously. Pour off supernatant through a 500 micron sieve. Repeat this process five times (minimum). Pour remainder from bucket through a 1 mm sieve. Check for invertebrates on sieve. Repeat with four other grab and core samples.</i></p> <p><i>For intertidal benthic invertebrates that are not well quantified by core sampling (e.g. mud prawns, sand prawns, some crabs), count hole densities of each species in quadrates of minimum area 0,25m², with five replicates at each station.</i></p> <p><i>The following need to be recorded at each site:</i></p> <ul style="list-style-type: none"> ▪ <i>Identify fauna to lowest taxon</i> ▪ <i>Record animal density and species abundance (animals per m²)</i> ▪ <i>Record the presence of Zostera.</i> <p><i>At each station, sediment samples need to be collected for particle size distribution (250 ml) and organic content (250 ml). Analyse using standard techniques.</i></p> <p><i>Macrocrustaceans: Quantitative sampling for macrocrustaceans should be conducted during neap tides (mid to high tide), at the same stations used for zooplankton. Use a benthic sled (80 cm x 80 cm, 500 micron mesh) with flow meter to collect sample and tow for about 30 meters diagonally across the estuary. Take two samples at each station. Set two prawn/crab traps per station overnight (more applicable to subtropical areas).</i></p> <p><i>Use <u>appropriate</u> gear to sample shoreline (e.g. marginal vegetation) for size class distribution of dominant organisms in those areas.</i></p> <p><i>Identify fauna to lowest taxon. Record number of species and determine densities.</i></p>

SPATIAL SCALE	<p><i>A sampling station is defined as a specific location in the estuary (at a specific 'distance from the mouth') from where a number of replicates are collected.</i></p> <p><i>Sampling stations must be representative of the salinity zones characteristic of a particular estuary, which typically include (these zone should be indicated on a map):</i></p> <ul style="list-style-type: none"> ▪ <i>Fresh (representative of river)</i> ▪ <i>0–10 ppt</i> ▪ <i>10–20 ppt</i> ▪ <i>20–35 ppt</i> <p><i>Within each salinity zone, representative habitats need to be sampled, such as:</i> <i>Submerged macrophytes (e.g. Zostera beds)</i> <i>Soft sediments (sand/muddy sand/fine mud), hard (rocky areas) and organic rich areas.</i></p> <p><i>Benthic invertebrate stations need to include, in addition to the above, inter-tidal bird feeding areas.</i></p> <p><i>Where benthic invertebrates are included in long-term monitoring programmes, stations need to incorporate areas within the estuary where the habitat types are vulnerable to changes in river inflow.</i></p> <p><i>As a guideline, the number of stations in a small estuary (< 5 km long) should not be less than five, distributed along the entire length of the estuary, covering the salinity zones and habitat types as described above. Small systems with high habitat diversity may require more stations (in estuaries where the salinity regime is uniform, the selection of stations should focus on different habitat types).</i></p> <p><i>For larger estuaries (> 5 km long), 10 to 15 stations selected geographically along the entire length of the estuary, covering the salinity zones and habitat types as described above, can be used as the guideline (although this may vary depending on habitat diversity of a system). Stations should preferably be set at fixed intervals or positions. A rough estimate for setting the distance between stations is to divide the length of the estuary by 10 (i.e. if an estuary is 30 km long, the distance between stations should be about 3 km).</i></p> <p><i>In systems with large cross-sectional areas (e.g. estuarine bays), sampling stations should also be selected along cross-sections.</i></p>
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TEMPORAL SCALE	INTERMEDIATE LEVEL	COMPREHENSIVE LEVEL
	<p><i>Zooplankton, benthic invertebrates and macrocrustaceans: One survey in summer/spring and one survey in winter each year for two years. It is important that, at the time of sampling, the state of the estuary, as represented by the extent of saline intrusion and the state of the mouth, must be representative of that particular season.</i></p> <p><i>For temporarily open/closed estuaries, one survey needs to be conducted in a stable closed phase and one in a stable open phase.</i></p>	<p><i>Zooplankton, benthic invertebrates and macrocrustaceans: To be conducted in four seasons over two years (i.e. in spring, summer, autumn and winter in each year). At the time of sampling, the state of the estuary, as represented by the extent of saline intrusion and the state of the mouth, must be representative of that particular season.</i></p> <p><i>For temporarily open/closed estuaries, at least one survey must be conducted in a stable closed phase and at least two surveys in the stable open phase.</i></p>
	LONG-TERM MONITORING PROGRAMME (where selected as indicator)	
	<i>Zooplankton</i>	<i>Two years after implementation conduct a summer and winter survey followed by a summer and winter survey every three years thereafter.</i>
	<i>Benthic invertebrates</i>	<i>Two years after implementation conduct a summer and winter survey followed by a summer and winter survey every three years thereafter.</i>
<i>Macrocrustaceans</i>	<i>Two years after implementation conduct a summer and winter survey followed by a summer and winter survey every three years thereafter.</i>	
IMPORTANT NOTES: INVERTEBRATES		

- *Because of the high variability in invertebrates in response to flow it is important to sample over two years to obtain the required confidence level (medium for intermediate level and high for comprehensive level).*
- *Total lack of information on invertebrates in most of South Africa's estuarine systems is the reason for the greater intensity (temporal scale) of sampling for this component to get the required confidence. There is also a rapid change in community composition and abundance over time (weeks to months). Sampling is even more intensive for zooplankton because of their rapid response over time.*
- *As far as possible, the invertebrate and macrophyte sampling stations should be matched to be able to link habitats with invertebrate characteristics.*
- *Water (salinity, temperature, pH, dissolved oxygen and turbidity) and sediment quality (sediment grain size and organic content) measurements need to also be collected during the invertebrate surveys. Combining water and sediment quality surveys on a particular estuary with the invertebrate surveys does this most cost-effectively.*
- *For invertebrate surveys, seven sediment grain-size categories should be used, ranging from mud to very coarse sand. Each category relates to a particular size diameter in the following manner:*
- *>2 mm: > very coarse sand; 2–1 mm: very coarse sand; 1–0,5 mm: coarse sand; 0,5–0,25 mm: medium sand; 0,25–0,125 mm: fine sand; 0,125–0,0625 mm: very fine sand; <0,0625 mm: mud (silt and clay).*
- *The percentage organic content of sediments can roughly be classified as:*
<0,5%: very low; 0,5%–2%: low; 1%–2%: moderately low; 2%–4%: medium; > 4%: high.

Fish:

<p>SAMPLING PROCEDURE</p>	<p>Conduct fish surveys using gear appropriate to the habitat of a particular estuary, but with seine nets and gill nets as primary gear.</p> <p>Seine nets: 30 m x 2 m x 15 mm multifilament bar mesh in the wings and a 5 mm bar mesh in the purse.</p> <p>Seine nets should be 30 m long by 2 m depth. The cod end (bag, purse) and the wings 5 m either side of it should be 5 mm bar whereas the remaining 15 m of each wing can be 15 mm bar mesh. This is required to adequately sample estuarine and 'faster moving' marine species. The net should be weighted so that it sinks below the surface when set in water deeper than 2 m (i.e. the distance between the lead and cork lines). A light net makes it more difficult to obtain a representative sample from weed and sandy areas, e.g. flatfish species tend to burrow in the sand and escape under a light seine.</p> <p>Gill nets: Monofilament gill nets should comprise at least three different mesh sizes within the range of 40–150 mm stretch mesh. Monofilament gill nets should comprise at least four nets (or panels) of which one net comprises 44, 48, 51 and 54 mm mesh, plus three more nets in the 75–150 mm stretched mesh range (e.g. 75, 100 and 145 mm stretched mesh).</p> <p>Other sampling methods that may be used where primary gears are not appropriate include:</p> <ul style="list-style-type: none"> ▪ Scoop nets (e.g. in extensive submerged macrophyte beds) ▪ Otter trawls (e.g. in deep channel areas) ▪ Cast nets (e.g. in inaccessible areas). <p>N.B. Where historic fish data for a particular estuary has been collected using mesh sizes that differ from the above, it is recommended that previous net dimensions be used.</p> <p>At each sampling station the following data need to be recorded:</p> <ul style="list-style-type: none"> ▪ Species lists ▪ Number of each species ▪ Size frequency distributions in total length.
<p>SPATIAL SCALE</p>	<p>A sampling station is defined as a specific location in the estuary (at a specific 'distance from the mouth') from where fish samples are collected using appropriate sampling gear (see above).</p> <p>Sampling stations must be representative of the salinity zones characteristic of a particular estuary, typically (these zone should be indicated on a map):</p> <ul style="list-style-type: none"> ▪ Fresh (representative of river) ▪ 0–10 ppt ▪ 10–20 ppt ▪ 20–30 ppt ▪ 30–35 ppt (at least one station should be in this range). It has been found that this salinity range supports a substantially different species composition than that found, for example in the range 20–30 ppt (S Lamberth, MCM & P Cowley, SAIAB, pers. comm.) <p>Within each salinity zone, representative habitats need to be sampled, such as:</p>

	<ul style="list-style-type: none"> ▪ Submerged macrophytes (e.g. <i>Zostera beds</i>) ▪ Sandy/muddy/rocky areas (representing different food sources). <p>As a guideline, the number of seine net stations in a small estuary (< 5 km long) should not be less than five, distributed along the entire length of the estuary, covering the salinity zones and habitat types as described above. Small systems with high habitat diversity may require more stations. Gill net samples do not need to be in the same quantity as seine samples. In small estuaries these nets could be used in the mouth, middle and upper reaches.</p> <p>For larger estuaries (> 5 km long), 10 to 15 seine net stations selected geographically along the entire length of the estuary, covering the salinity zones and habitat types as described above, can be used as the guideline (although this may vary depending on habitat diversity of a system). Stations should preferably be set at fixed intervals. A rough estimate for setting the distance between stations is to divide the length of the estuary by 10 (i.e. if an estuary is 30 km long, the distance between stations should be about 3 km). For larger estuaries gill nets can be used at every two to three seine net sites. For example, the Breede River Estuary was sampled at the mouth and thereafter every 5 km upstream, approximately nine gill net sites over 40 km.</p>	
TEMPORAL SCALE	INTERMEDIATE LEVEL	COMPREHENSIVE LEVEL
	<p>One survey in summer/spring and one survey in winter/autumn to sample the spectrum of species in the system. It is important that, at the time of sampling, the state of the estuary, as represented by the extent of saline intrusion and the state of the mouth, must be representative of that particular season.</p> <p>For temporarily open/closed estuaries, one survey needs to be conducted in a stable closed phase and one in a stable open phase.</p>	<p>Seasonally over one year, i.e. in spring, summer, autumn and winter. The temporal scale needs to address recruitment patterns as well as species distribution within habitats in different seasons. Also, at the time of sampling, the state of the estuary, as represented by the extent of saline intrusion and the state of the mouth, must be representative of that particular season.</p> <p>For temporarily open/closed estuaries, at least one survey must be conducted in a stable closed phase.</p>
	LONG-TERM MONITORING PROGRAMME (where selected as indicator)	
<p>Permanently open estuaries: Two years after implementation conduct a summer and winter survey, followed by a summer and winter survey every three years thereafter.</p> <p>For temporarily open/closed estuaries, summer and winter surveys to be conducted within a three-year period to ensure that conditions representative of stable open and closed phases are captured.</p> <p>Sampling should be done immediately after any fish kill, followed by another one to two months after the event. This should be budgeted for in a contingency fund.</p>		

IMPORTANT NOTES: FISH

- *Gill nets are extremely valuable in determining the seasonal changes in the along-stream distribution of the adults of large fish species. For example, it was found that 44 mm, 48 mm, 51 mm and 54 mm mesh sizes were needed to obtain a representative sample of the different mullet species in the south-western Cape. The 44 mm mesh catch tends to be dominated by *Liza dumerilii*, the 48 mm by *L. richardsonii* and the 51 mm and 54 mm by *L. tricuspidens*, *Myxus capensis* and *Mugil cephalus*. (Note: Monofilament nylon nets should be used, not woven nylon nets, as the latter have a completely different capture efficiency).*
- *Non-destructive sampling should be practiced where possible. The survival rate of larger fish is much greater if they are removed from a gill net by cutting the mesh (easily repaired afterwards), whereas most seined fish can be measured and released alive. If there are abundant fish in a sample, 100 individuals of a species should be measured, the rest counted and released. However, it must be accepted that some fish, especially clupeids, die very easily.*
- *The primary goal of fish sampling is to obtain species and size composition of the fish present in the system.*
- *Gill nets are necessary to sample those fast-swimming species and larger individuals that are not captured in the seine nets.*
- *Monofilament gill nets of various mesh sizes can, for example, be purchased from Laaiplek Handelshuis and Alnet (Pty) Ltd.*
- *Water quality measurements (salinity, temperature and other physico-chemical properties) need to be collected during the fish surveys. Combining water quality surveys on a particular estuary with the fish surveys does this most cost effectively.*
- *Fish are more responsive to flow changes than for example estuarine invertebrates or vegetation, making these good indicator species.*
- *In temporarily open/closed estuaries not all pre-selected sites may be assessable with the same gear during the various sampling trips. This would especially be the case for sites selected on habitat variability, e.g. protective backwater areas. This is an acceptable practice, as long as representative sites are monitored in the same salinity regime to allow for extrapolation.*
- *The advantages of using fish as indicators include (Whitfield & Elliot, 2002):*
 - *Fish are present in all aquatic systems*
 - *Life history and environmental response information is available for most species*
 - *Relatively easy to identify and samples can be processed in the field, with the fishes being returned to the water (non-destructive sampling)*
 - *Communities usually include a range of species that represent a variety of trophic levels*
 - *Fish are relatively long-lived and therefore provide a integrative record of environmental stress*
 - *Fish contain many life forms and functional guilds and are likely to cover a number of components of aquatic ecosystems affected by change*
 - *Both sedentary and mobile and thus will reflect localised stressors as well as provide a broader assessment of effects*
 - *Acute toxicity and stress effects can be evaluated in the laboratory*
 - *High public awareness value, i.e. general public relate more to information on fish than on invertebrates or plants;*
 - *Societal costs of environmental degradation (e.g. cost-benefit analyses) are more readily determined in terms of the economic, aesthetic and conservation values attached to fish.*
- *Difficulties associated with using fish as indicators include (Whitfield & Elliot 2002):*
 - *Selective nature of sampling gear for certain habitats, sizes and species of fish*

IMPORTANT NOTES: FISH

- *Mobility of fish on seasonal time scales can lead to sampling bias*
- *Fish may be relatively tolerant to substances chemically harmful to other life forms*
- *Fish can swim away from a disturbances, thus avoiding localised exposure to pollutants or adverse environmental conditions*
- *Estuarine environments that have been physically altered by humans may still contain diverse fish assemblages*

Birds:

SAMPLING PROCEDURE	<p><i>Undertake full bird counts of all water-associated birds, recording the following information:</i></p> <ul style="list-style-type: none"> ▪ <i>Divide the estuary into counting sections on the basis of habitat type (e.g. sandy intertidal, muddy intertidal, mangroves, Zostera beds, salt marsh) and record on a map.</i> ▪ <i>For each counting section and for all estuaries, provide:</i> <ul style="list-style-type: none"> ○ <i>Species list</i> ○ <i>Number of birds of each species (at low tide)</i> ○ <i>State of the habitat at the time of observation (or photo of site)</i> ○ <i>Levels of human disturbance at time of counting</i> ○ <i>Identify key areas for feeding, roosting and breeding on the estuary and adjacent floodplain</i> ○ <i>Identify and count high-tide aggregations of feeding or roosting birds as far as possible</i> ○ <i>Identify breeding areas and count breeding aggregations as far as possible.</i> 	
SPATIAL SCALE	<p><i>The area covered must include the entire estuary and its floodplain, incorporating all habitats used by water-associated birds for feeding, breeding or roosting.</i></p> <p><i>The upper boundary of the study area is the same as that for the overall study, i.e. the upper geographical boundary of the estuary.</i></p> <p><i>The seaward boundary, which is regularly crossed by seabird species such as cormorants, gulls and terns, is most difficult to define. As a guideline, it should include the full tidal delta area and sand bars up to the back line of breakers outside the estuary mouth.</i></p> <p><i>The sensible lateral extension would be different for each estuary, and may include rocky bars, etc. Thus it is important to furnish a map of the area counted. Any major bird roosts in close proximity to the estuary should be counted and mapped.</i></p>	
TEMPORAL SCALE	INTERMEDIATE LEVEL	COMPREHENSIVE LEVEL
	<p><i>One summer month count when the tide in the estuary is at its lowest. In the case of temporarily open/closed estuaries this must be conducted when the mouth is open. However, in estuaries with a high variability in avifauna, three summer and two winter counts over one year may be required to obtain a medium confidence.</i></p>	<p><i>Birds to be counted every month for one year. Alternatively conduct three summer month counts (September, December and March) and two winter month counts (June and July) each year over two years. In the case of temporarily open/closed estuaries, at least one count must be done in summer when the mouth is open, in addition to fulfilling the above requirements.</i></p>

	LONG-TERM MONITORING PROGRAMME (where selected as indicator)
	Conduct a summer and a winter survey every year.
IMPORTANT NOTES: BIRDS	

- Where bird sampling is done according to sections, the section or station number needs to be labelled as 'distance from mouth'.
- Ideally, the summer count should be in a consistent month, with the same month being used for the monitoring programme. Thus, unless there is a problem with mouth closure, the summer count should always be in February or March, and never after the end of March. Numbers of birds in an estuary change markedly throughout the year, with summer numbers often continuing to increase from spring right up until the end of March, after which there is a dramatic drop in early April following the departure of long-distance Palearctic migrants. Counting birds earlier than February would not only potentially lead to an underestimate of maximum bird numbers, but would be compromised in quality by presence of summer holidaymakers. Human disturbance on estuaries is known to have a significant impact on numbers of birds counted on estuaries.
- Bird numbers fluctuate cyclically, in fact often with a three-year periodicity. If you count every two years you will completely lose this pattern, which will make interpretation of trends very difficult indeed. Therefore, in the long-term monitoring programme, birds should be sampled every year.
- To investigate major food sources of key piscivorous, invertebrate and macrophyte feeders, stomach content can be used, but this requires specialised equipment and expertise. In addition, estuarine birds are highly adaptive feeders, and describing the diet at one point in time (from a limited sample) may drive one to a rather simplistic and erroneous conclusion about the impact of changes in the food base. Any trained ornithologist would be able to use available understanding on bird diets and behavioural ecology, coupled with an understanding of their food base, to predict what will happen, with no less certainty than if you went out and stomach-pumped a limited sample of birds.
- The Co-ordinated Waterbird Counts (CWAC) monitors South Africa's waterbird populations and the conditions of the wetlands that are important for waterbirds. This is done by means of a programme of regular mid-summer and mid-winter censuses at a large number of South African wetlands and estuaries, at regular six-monthly intervals. CWAC currently monitors over 350 wetlands around the country. For a reserve determination it is important to check the availability of CWAC data on a specific estuary. Where available, CWAC data can be acquired at a cost of between R10 000 and R15 000 per system (allow for this in the budget). (http://web.uct.ac.za/depts/stats/adu/p_cwac.htm)
- It is recommended that the Directorate: Resource Directed Measures provide CWAC with a list of priority estuaries. In this way, those estuaries could be considered for inclusion in their monitoring network.
- Although the selection of components in long-term monitoring programmes will be selected on a site-specific level, birds are likely to be important indicators in the following instances:
 - Large permanently open estuaries
 - Estuarine lakes
 - Estuarine bays
- If there are a number of rare and/or endangered species (diversity and/or density)
- Estuaries known to be utilised during migration.

3.2 Eastern Cape Estuaries Management Programme Monitoring Protocols

This monitoring protocol forms part of the larger Eastern Cape Estuaries Management Programme aimed at monitoring the achievement of pre-defined operational goals, and was developed through a series of workshops with scientists and managers and tested in co-operation with stakeholders associated with the Swartkops and Tyolomnqa estuaries in the Eastern Cape (McGwynne & Adams, 2004).

The protocol identifies 10 categories of indicators, namely:

- Hydrodynamic and sedimentary processes;
- Water quality;
- Biodiversity;
- Human population growth;
- Control of human activities;
- Planning and development;
- Law enforcement;
- Co-operative governance and co-management;
- Effective management; and
- Satisfaction of basic human needs.

Managers working together with or as part of co-management forums are the target user group and to accommodate limits in their resources, the indicators are presented in three levels of increasing skill requirements, time and cost. In addition, the set can be customised to meet management objectives that are bound to differ between estuaries (McGwynne & Adams, 2004).

Each indicator is embedded in an interpretive framework where defined end-points signify TPCs. These are defined as broad statements of intent in the form of management guidelines. To assist the practical implementation of the indicators, a handbook incorporating an interpretive framework is presented as an appendix (McGwynne & Adams, 2004).

The monitoring protocol proposes the following set of indicators for South African estuaries within each of the indicator categories. Also indicated in the tables below are whether a particular indicator is suitable as a pressure, state or response indicator within the context of the pressure-state-response approach in environmental assessment (the numbering provides links to relevant sections in the handbook – refer to McGwynne and Adams, 2004).

Table 3. Eastern Cape Estuaries Monitoring Protocol (McGwynne & Adams, 2004)

NO.	PRESSURE/ STATE/ RESPONSE	ISSUE 1. HYDRODYNAMIC AND SEDIMENTARY PROCESSES (HS 1-5)
<i>Objective:</i> Hydrodynamic regimes are managed to support natural sedimentary processes		
<i>Sub-objective:</i> The rate and volume of freshwater inflow maintain natural patterns of sediment movement		
<i>Operational goals (TPCs):</i> Specific for each estuary		
<u>Level 1 indicators</u>		
HS1	S	Record of freshwater inflow at gauges set up above the head of an estuary (if available, data can be obtained on request from DWAF)
HS2	S	State of estuary mouth (open or closed) through visual observations (temporarily open estuaries)
HS3	S	Frequency and duration of episodic events (e.g. floods, drought)
<u>Level 2 indicator</u>		
HS4	S	Sedimentation in the mouth
<u>Level 3 indicator</u>		
HS5	S	Changes in bathymetry as a measure of long-term sedimentation processes
NO.	PRESSURE/ STATE/ RESPONSE	ISSUE 2. WATER QUALITY (WQ 1-8)
<i>Objective:</i> Water quality is managed to maintain normal ecological processes		
<i>Sub-objectives:</i> (1) The quality and quantity of river inflow maintains natural nutrient cycles and salinity gradients and does not introduce pollutants (2) Surface water runoff and inflow from industrial and domestic effluent does not elevate nutrient, suspended sediment and bacteriological levels above the normal ranges, nor does it introduce or exacerbate toxic pollutant loading		
<i>Operational goals (TPCs):</i> Specific for each estuary		
<u>Level 1 indicators</u>		
WQ1	S	Concentrations of water quality parameters in river inflow (if available, data can be obtained on request from DWAF)
WQ2	P	Frequency of occurrence and location of: - fish and invertebrate mortalities - macro- and microalgal blooms - non-natural floating objects and surface contaminants - areas with bad smells
WQ3	S	Salinity distribution patterns
WQ4	S	Water transparency measured through secchi depth readings
WQ5	P	Concentration of bacteriological contaminants (total coliforms, E coli)
WQ6	P	Number and location of point-source effluent discharges and the type and volume of material discharged
<u>Level 2 indicator</u>		
WQ7	P/S	Concentration of constituents that determine water quality (e.g. nutrients [nitrite/nitrate, ammonia, reactive phosphate], dissolved oxygen)
<u>Level 3 indicator</u>		
WQ8	P	Concentrations of toxic substances (e.g. trace metals Cr, Pb, Zn, Mn, Sr, Cu) in sediments or biotissue

NO.	PRESSURE/ STATE/ RESPONSE	ISSUE 3. BIODIVERSITY (B 1-7)
<i>Objective: Biodiversity is maintained or improved</i>		
<i>Sub-objective: The natural diversity, distribution and abundance of plant, bird, fish and benthic invertebrate communities is maintained or restored</i>		
<i>Operational goals (TPCs): Specific for each estuary</i>		
<u>Level 1 indicators</u>		
B1	S	Presence and extent of plant communities
B2	P	Infestation of riparian vegetation by alien invasives
B3	S	Densities of intertidal mudprawns
<u>Level 2 indicators</u>		
B4	S	Waterbird counts (Co-ordinated Waterbird Counts [CWAC] programme)
B5	S	Fish abundance measured as catch per unit effort (CPUE) (rod and line)
B6	S	Extent of natural area remaining per habitat type, and the degree of habitat fragmentation
B7	R	Location and proportion of estuary habitat type under formal protection (e.g. Marine Protected Area, Nature Reserve, Marine Reserve: Regional Application)

NO.	PRESSURE/ STATE/ RESPONSE	ISSUE 4. HUMAN POPULATION GROWTH (HP 1-2)
<i>Objective: Human population size and distribution are managed so that these factors do not reduce the quality of human life or the probability of achieving the vision for the estuary</i>		
<i>Sub-objective: Human population size and distribution do not negatively impact the well-being of communities nor the capacity of the ecosystem to function normally</i>		
<i>Operational goals (TPCs): Specific for each estuary</i>		
<u>All Level 2 indicators</u>		
HP1	S/P	Population distribution and density in suburbs, townships and informal settlements associated with the estuary
HP2	P	Annual population growth rate

NO.	PRESSURE/ STATE/ RESPONSE	ISSUE 5. CONTROL OF HUMAN ACTIVITIES (HA 1-4)
<i>Objective: Human use in terms of recreational and subsistence activities is managed at levels that satisfy human needs without compromising the integrity of social and ecological systems</i>		
<i>Sub-objectives: (1) Non-consumptive human activities (swimming, skiing, sailing, birding, nature walking) are maintained within the recreational carrying capacity of the estuarine environment (2) Consumptive activities (fishing, bait collecting, tree harvesting) are maintained at sustainable levels (3) By-products of human activities do not alter habitats or ecological processes</i>		
<i>Operational goals (TPCs): Specific for each estuary</i>		
<u>All Level 1 indicators</u>		
HA1	P	Number of persons visiting the estuary and their activity (including fishing)
HA2	P	Number of bait collectors and the method of bait extraction (suction pump, spade, fork, tin), rate of bait removal, and the number of licensed collectors
HA3	P	Number of fishing competitions
HA4	P	Litter accumulation

NO.	PRESSURE/ STATE/ RESPONSE	ISSUE 6. PLANNING AND DEVELOPMENT (PD 1–4)
<p><i>Objective:</i> Development is managed to meet social and economic needs without impacting on the health/integrity of the estuary</p> <p><i>Sub-objectives:</i> (1) Land use alongside an estuary is guided by ecologically sound and socially equitable local and regional planning strategies (2) Land-use planning for estuaries and catchments incorporates the principles of integrated environmental management</p> <p><i>Operational goals (TPCs):</i> Specific for each estuary</p>		
<i>Level 1 indicator</i>		
PD1	S/P	Nature and extent of land use and infrastructure associated with the estuary and catchment
<i>Level 2 indicators</i>		
PD2	P	Number, type, extent and production of mariculture operations
PD3	P	Number of applications for new development or rezoning of land associated with the estuary
PD4	R	Use of tools such as strategic environmental assessments (SEAs) and estuary management plans (EMPs) to guide planning and development (regional)

NO.	PRESSURE/ STATE/ RESPONSE	ISSUE 7. LAW ENFORCEMENT (LE 1–4)
<p><i>Objective:</i> Legislation to control human use of estuary resources is enforced effectively</p> <p><i>Sub-objectives:</i> (1) The level of law enforcement is adequate to monitor compliance to legislation effectively (2) Penalties imposed for contravening regulations are effective in reducing illegal activities</p> <p><i>Operational goals (TPCs):</i> Specific for each estuary</p>		
<i>All Level 1 indicators</i>		
LE1	R	Number of law enforcement officers assigned to an estuary and the frequency of patrols
LE2	P	Number of offences, arrests and convictions for contravening regulations stipulated in the Marine Living Resources Act (No 18 of 1998)
LE3	R	Number and nature of penalties imposed for infringement of regulations governing effluent discharge
LE4	R	Enforcement and monitoring of development conditions set by environmental impact assessment procedures

NO.	PRESSURE/ STATE/ RESPONSE	ISSUE 8. CO-OPERATIVE GOVERNANCE AND CO-MANAGEMENT (CGC 1–5)
<p><i>Objective:</i> Management by local, provincial and national government is integrated and co-ordinated, and co-responsibility partnerships are forged between government, parastatals, the private sector, special interest groups and the scientific research community</p> <p><i>Sub-objectives:</i> (1) Communication and co-operation between management authorities is such that policies, strategies and projects are integrated and co-ordinated (2) Estuary forums are effective co-management structures (3) Co-operation between estuary management authorities and catchment management agencies and/or water-user associations aligns management objectives and improves efficiency and effectiveness</p> <p><i>Operational goals (TPCs):</i> Specific for each estuary</p>		
<i>All Level 2 indicators</i>		
CGC1	S	Record of management authorities (local and provincial), their areas of jurisdiction, frequency of interaction and degree of co-operation in terms of joint projects
CGC2	R	Number of estuaries where management forums are established to engage government in planning and management issues (regional)

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CGC3	R	Number, type and cost (if applicable) of projects or initiatives that involve co-operation between local and/or provincial estuary management and the estuary forum
CGC4	R	Number of river catchments where catchment management agencies, water-user associations and catchment forums are established to manage freshwater resources and water related activities (regional)
CGC5	S	Degree of interaction and co-operation (in terms of joint projects) between the management of estuaries (local and provincial government and estuary forums) and the management of catchments (catchment management agencies, water-user associations, catchment forums) (local and regional)

NO.	PRESSURE/ STATE/ RESPONSE	ISSUE 9. EFFECTIVE MANAGEMENT (EM 1–6)
<i>Objective:</i> Estuaries are recognised as important ecological, social and economic assets and managers are adequately equipped to act effectively in terms of current legislation and international obligations		
<i>Sub-objectives:</i> (1) Estuary managers are aware of current legislation pertaining to estuaries as well as South Africa's commitments to international agreements and conventions (2) Estuary managers have the necessary tools, manpower, competence and budget to achieve their goals and objectives (3) Conservation issues are communicated at all levels		
<i>Operational goals (TPCs):</i> Specific for each estuary		
<u>All Level 2 indicators</u>		
EM1	S	Record of international agreements and conventions to which South Africa is a signatory, and their implications for estuary management
EM2	S	Record of current and proposed environmental legislation and its implications for estuary management
EM3	S	Local and provincial government capacity in terms of manpower and skills required for effective management, and the number and type of capacity-building projects
EM4	R	Local and provincial government budget for research, environmental education and/or other estuary-related projects
EM5	R	Environmental reporting by government departments
EM6	R	Number of estuaries covered by GIS mapping (regional)

NO.	PRESSURE/ STATE/ RESPONSE	ISSUE 10. SATISFACTION OF BASIC HUMAN NEEDS (HN 1–23)
<i>Objective:</i> Communities associated with estuaries enjoy minimum standards of nutrition, housing, health, education, employment opportunities and security to ensure their well-being in the long term so that they do not reduce the probability of achieving the vision for the estuary		
<i>Operational goals (TPCs):</i> Specific for each estuary		
<u>All Level 2 indicators</u>		
<i>Sub-objective (1):</i> Every member of the community has access to an adequate supply of nutritious food, clothing, water and household energy		
HN1	S/P	Number and proportion of households dependent on estuary resources for subsistence
HN2	S/P	Number and proportion of households dependent on food and clothing donations
HN3	S	Access to potable water
HN4	S	Household energy use per energy type (electricity, gas, paraffin, wood, coal, animal dung, other)
<i>Sub-objective (2):</i> Every member of the community can obtain adequate, affordable housing that includes sanitation and waste disposal		

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NO.	PRESSURE/ STATE/ RESPONSE	ISSUE 10. SATISFACTION OF BASIC HUMAN NEEDS (HN 1–23)
HN5	S/P	Number of persons/families living in informal shacks
HN6	S/P	Number of persons/families on waiting lists for proper houses and the duration of the waiting period
HN7	S/P	Number and proportion of households with adequate sewage-disposal facilities
HN8	S/P	Storage of household waste and frequency of waste collection/disposal
<i>Sub-objective (3): Every member of the community can achieve optimum health</i>		
HN9	S	Proportion of the community with access to (i) primary health care (clinics) and (ii) comprehensive medical care, including dental and preventative care
HN10	S	Number of casualty visits, hospitalisations and deaths due to malnutrition, exposure, sickness, violence or inadequate medical care
<i>Sub-objective (4): Every member of the community can obtain an education appropriate for his/her needs, ambitions and abilities to enable him/her to function as a responsible member of society</i>		
HN11	S	Adult (older than 18 years) functional literacy (passed Grade 6)
HN12	S	Proportion of community with Grade 12
HN13	S	Proportion of high school graduates furthering their education at universities or colleges
HN14	S	Number and types of community projects to develop capacity
<i>Sub-objective (5): Every member of the community in the economically active group obtains employment that provides a living wage</i>		
HN15	S/P	Unemployment rate (number of people in the economically active age group unemployed and seeking work)
HN16	S/P	Number and proportion of households dependent on state grants (i.e. pensions and/or child support grants)
HN17	S/P	Number and proportion of households where the total income is at or below the minimum living level (R800 per month)
HN18	S/P	Unemployment rate of the greater region
<i>Sub-objective (6): Every member of the community feels valued as part of a viable and stable community with defined values and aspirations</i>		
HN19	S	Number and proportion of families with both parents in the home
HN20	S	Effectiveness of communication mechanisms in the community
HN21	S	Number of police stations (permanent and satellite) per area and the frequency of patrols
HN22	S	Crime rate
HN23	S	Number of projects adopted on a community level to address issues of concern

4. Proposed Estuarine Health Programme for the CFR

An Estuarine Health Programme (EHP) is envisaged to be a cost-effective and practical long-term field measurement/monitoring programme that will provide data to assess the health status of estuaries. An essential component to be addressed as part of this programme will be the design and maintenance of a national estuarine database (including a user-friendly interface).

An important outcome of an EHP is the 'State of Estuaries Reporting', although the programme should also be designed such that it supports operational management of estuaries, in terms of:

- Conservation planning (included in the Objective-setting phase);
- Infrastructure and development;
- Water quantity and quality; and
- Exploitation of marine living resources.

The context of an EHP can be schematically illustrated as follows:

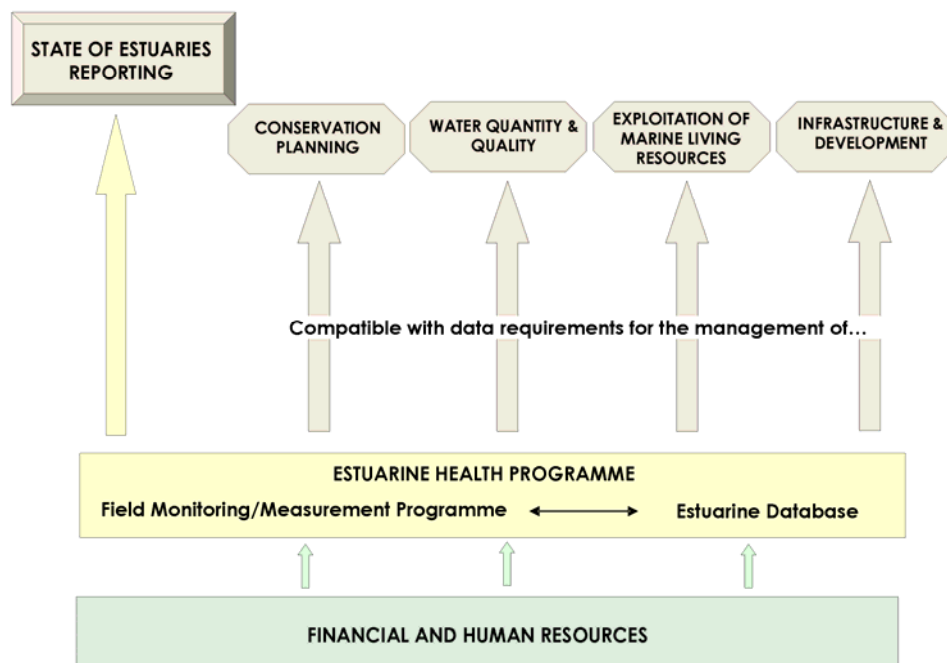


Figure 3. Components of an Estuarine Health Programme

One of the aims of the C.A.P.E. Estuaries Programme is to design and pilot-test an EMP for the CFR (Olifants to Swartkops estuaries), with the ultimate goal of expanding this to a national EHP, complementary to the National River Health Programme, an aspect that will be addressed in the National Estuarine Management Protocol as proposed in the National Environmental Management: Integrated Coastal Management Bill.

Although the design and pilot-testing of an EHP for the CFR will be a separate project within the C.A.P.E. Estuaries Programme, a project of such nature should include the following key tasks:

- Selection of monitoring parameters (indicators), based on the requirements as per 'State of Estuaries Reporting' and estuarine management initiatives
- Selection and development of assessment tools, presentation of data (e.g. icons) and output formats for 'State of Estuaries Reporting'
- A prototype application of 'State of Estuaries Reporting' format (web-based)
- Verification of ability of the EHP to support/inform estuarine management, through consultation with relevant management authorities
- Development of a web-based estuarine database
- Preparation of training material.

Information provided in the report, together with the learning to be gained in the case studies, should also provide valuable guidance for the design of an EHP of this nature.

However, the successful implementation of the EHP will depend on:

- Development of a comprehensive human resource plan that will allow the effective roll-out of the EHP to estuaries in the CFR, and, ultimately the entire coast of South Africa, including proper training programmes.
- Development of a financial resource plan that will be able to fund such activities in a sustainable manner – e.g. linking the activities within the EHP to responsibilities and mandates of specific lead government agencies as per legislation.

5. References

- Australia and New Zealand Environment and Conservation Council (ANZECC) 2000. Australian Guidelines for Water Quality Monitoring and Reporting. National Water Quality Management Strategy No. 7. Canberra, Australia. ISBN 0 642 19562 5.
- Boyd, AJ, Barwell, L & Taljaard, S 2000. Report on the National Estuaries Workshop. 3-5 May 2000, Port Elizabeth, South Africa. Report No. 2, Marine and Coastal Management Implantation Workshops. Cape Town: Chief Directorate Marine and Coastal Management.
- Department of Water Affairs and Forestry (DWAf) (2004) Water resource protection and assessment policy implementation process. Resource directed measures for protection of water resource: Methodology for the Determination of the Ecological Water Requirements for Estuaries. Version 2. Pretoria.
- Department of Water Affairs and Forestry (DWAf) 1995. South African Water Quality Guidelines for Coastal Marine Waters, Volume 1. Natural Environment, Volume 2. Recreational Use, Volume 3. Industrial Use, Volume 4. Pretoria: Mariculture
- Kleynhans, C.J. 2003. Aspects of ecological reserve monitoring. The role of the adaptive environmental assessment and management (AEAM) process within monitoring, and the reserve process in general. Talk presented to stakeholders by the Department of Water Affairs and Forestry.
- McGwynne, L. & Adams, J. 2004. Protocols contributing to the management of estuaries in South Africa, with a particular emphasis on the Eastern Cape province. Volume II, Report E, A monitoring protocol for South African estuaries, *Water Research Commission Report no. TT 237/04*.
- Rogers, K. & Biggs, H. 1999. Integrating indicators, endpoints and value systems in strategic management of the rivers of the Kruger National Park. *Freshwater Biology* 41: 439–451.
- Taljaard, S., Van Niekerk, L., Huizinga, P. & Joubert, W. 2003. Resource Monitoring Procedures for Estuaries. For application in the Ecological Reserve Determination and Implementation Process. *Water Research Commission Report no. 1308/1/03*. Pretoria.
- Turpie, J.K., Adams, J.B., Joubert, A., Harrison, T.D., Colloty, B.M., Maree, R.C., Whitfield, A.K., Wooldridge, T.H., Lamberth, S.J., Taljaard, S. & Van Niekerk, L. 2002. Assessment of the conservation priority status of South African estuaries in management and water allocation. *Water SA* 28(2): 191–205.
- United States Environmental Protection Agency (US-EPA). 2003. Elements of a State Water Monitoring and Assessment Program. Assessment and Watershed Protection Division. Office of Wetlands, Oceans and Watershed. United States Environmental Protection Agency. EPA 841-B-03-003. www.epa.gov/owow/monitoring/repguid.html.

Whitfield, A K and Elliot, M. 2002. Fishes as indicators of environmental and ecological changes within estuaries: a review of progress and some suggestions for the future. Journal of Fish Biology 61(Supplement A): 229-250.

*Appendix A:
Existing Resource Monitoring Programmes undertaken
in South African Estuaries*

Monitoring Programmes for Implementation in South African Estuaries

A number of resource monitoring programmes have been undertaken in South African estuaries over recent years, as summarised below (refer to Taljaard *et al.*, 2003 for further details), of which some have been terminated over the past two to three years.

Long-term monitoring (> 5 years)

<i>Estuary</i>	<i>Organisation</i>	<i>Water levels/ Observations</i>	<i>Flow gauging</i>	<i>Sediment</i>	<i>Water quality</i>	<i>Flora</i>	<i>Inverts</i>	<i>Fish</i>	<i>Birds</i>
Klein	MCM/CSIR	X			X				
Bot	MCM/CSIR	X			X				
Heuningnes	DWAF/ MCM/ CapeNature	X						X	
Great Brak	DWAF/CSIR	X	X	X	X	X	X		
Swartvlei and Wilderness	IWR/ /SANP	X	X	X	X	X		X	X
East Kleinemonde	SAIAB	X						X	
Mkomazi	University of Natal	X	X		X	X	X	X	X
Siyaya	CRUZ			X	X		X	X	X
Mhlathuze	CRUZ	X	X	X	X		X	X	X
Nhlabane	CRUZ	X	X	X	X		X	X	X
St Lucia	KZN Wildlife	X	X		X	X		X	X
Kosi	KZN Wildlife				X?	X		X	

National Monitoring or Survey Programmes

<i>Programme</i>	<i>Organisation</i>	<i>Water levels/ Observations</i>	<i>Flow gauging</i>	<i>Sediment</i>	<i>Water quality</i>	<i>Flora</i>	<i>Inverts</i>	<i>Fish</i>	<i>Birds</i>
Continuous water level recording (currently implemented in 29 estuaries)	DWAF	X							
Aerial photographs – terminated (included all estuaries along SA coast)	DEAT/CSIR	X							
Flow gauging stations capturing total run-off of catchment to estuaries	DWAF		X						
Mouth observation programme (currently implemented in 10 estuaries)	CSIR	X							
Topographical surveys – terminated (included 47 estuaries along SA coast)	DEAT/CSIR			X					

Monitoring

National Monitoring or Survey Programmes

Programme	Organisation	Water levels/ Observations	Flow gauging	Sediment	Water quality	Flora	Inverts	Fish	Birds
State of estuaries reporting – terminated (included 250 estuaries along SA coast)	DEAT/CSIR			X				X	
Co-ordinated Water Bird Counts – CWAC (currently implemented in 24 estuaries)	UCT								X
National Marine and Estuarine Linefish Survey (to include aerial monitoring of all estuaries, ground monitoring of 50 estuaries)	MCM							X	
Botanical importance rating (Included ~70% of estuaries along SA coast)	NMMU					X			
National sediment monitoring programme (terminated <i>in situ</i> monitoring in rivers)	DWAF			X					

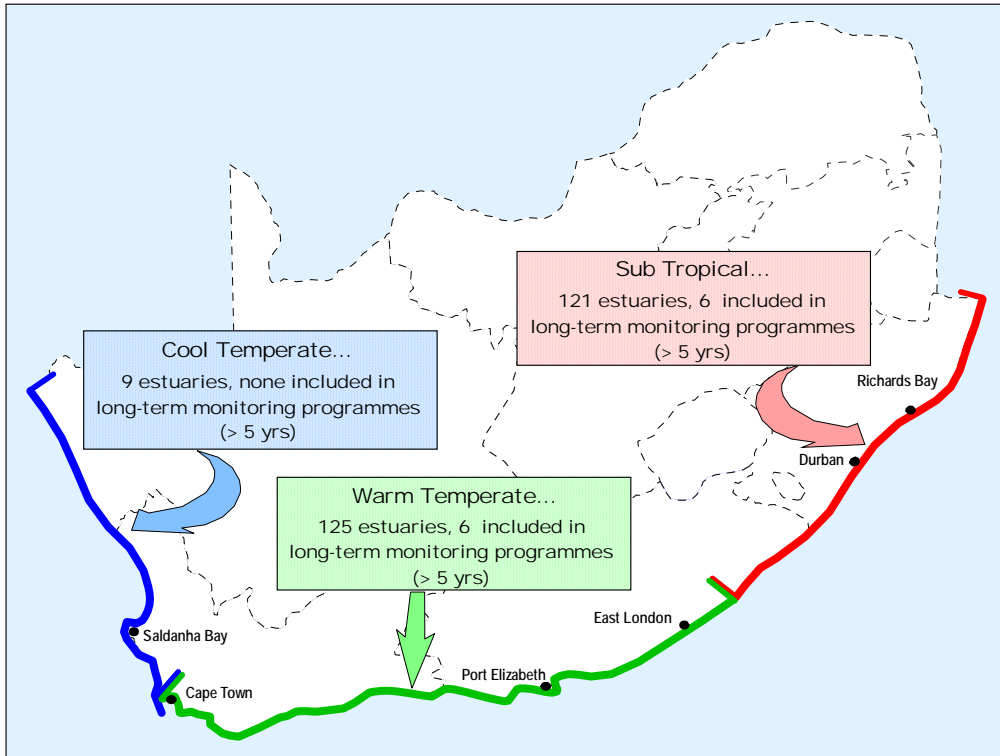
Short-term data-collection programmes or surveys (< 5 years)

Name	Organisation	Water levels/ Observations	Flow gauging	Sediment	Water quality	Flora	Inverts	Fish	Birds
Orange	BENEFIT	X				X	X	X	X
Berg	DWAF/ Anchor Associates	X	X	X	X	X	X	X	X
Olifants	DWAF	X	X		X	X	X	X	X
Sir Lowry's Pass	Cape Metro Council				X				
Eerste	Cape Metro Council				X				
Lourens	Cape Metro Council				X				
Soetwater River	Cape Metro Council				X				
Seekoei	Cape Metro Council				X				
Zandvlei	Cape Metro Council				X				
Silvermine	Cape Metro Council				X				
Diep	Cape Metro Council				X				

Short-term data-collection programmes or surveys (< 5 years)

<i>Name</i>	<i>Organisation</i>	<i>Water levels/ Observations</i>	<i>Flow gauging</i>	<i>Sediment</i>	<i>Water quality</i>	<i>Flora</i>	<i>Inverts</i>	<i>Fish</i>	<i>Birds</i>
Breede (Intermediate RDM)	DWAF	X	X		X	X	X	X	X
Klein Brak and Great Brak	NMMU						X		
Knysna (Intermediate RDM)	DWAF	X	X		X	X	X	X	X
Sout (Intermediate RDM)	DWAF	X	X		X	X	X	X	X
Swartkops	NMMU				X	X	X	X	
Kromme (Intermediate RDM)	DWAF	X	X	X	X	X	X	X	X
Great Fish	SAIAB/ NMMU				X	X	X	X	
Mpekweni	SAIAB/ NMMU				X	X	X	X	
Mtati	SAIAB/ NMMU				X	X	X	X	
Mgwalana	SAIAB/ NMMU				X	X	X	X	
Bira	SAIAB/ NMMU				X	X	X	X	
Gqutywa	SAIAB/ NMMU				X	X	X	X	
Keiskamma	SAIAB/NMMU				X	X	X	X	
Mngazi	NMMU	X	X	X	X	X	X	X	
Mnkazana	NMMU	X	X	X	X	X	X	X	
Thukela (Intermediate RDM)	DWAF	X	X	X	X	X	X	X	X
KZN Estuaries (mouth monitoring)	KZN Wildlife	X							
Durban Bay (harbour)	UN						X		

The number of long-term monitoring programmes that are still being implemented and that have been running for longer than five years is limited to only a few of South Africa's 255 functional estuaries, as illustrated below.



Currently, there are also a number of other research studies that deal with the development of monitoring initiatives for estuaries, albeit in a different context, such as the Eastern Cape Estuaries Management: Monitoring Project commissioned by the Water Research Commission, South African Integrated Spatial Information System (SA-ISIS) and the National Core Set of Environmental Indicators Project (refer to Appendix A for further details on these projects). The learning and experience gained through the above-mentioned initiatives will be taken into account in the development of monitoring procedures as outlined by this project.