THUKELA WATER PROJECT DECISION SUPPORT PHASE

RESERVE DETERMINATION MODULE
THUKELA SYSTEM ECOSPECS AND MONITORING REPORT

March 2004

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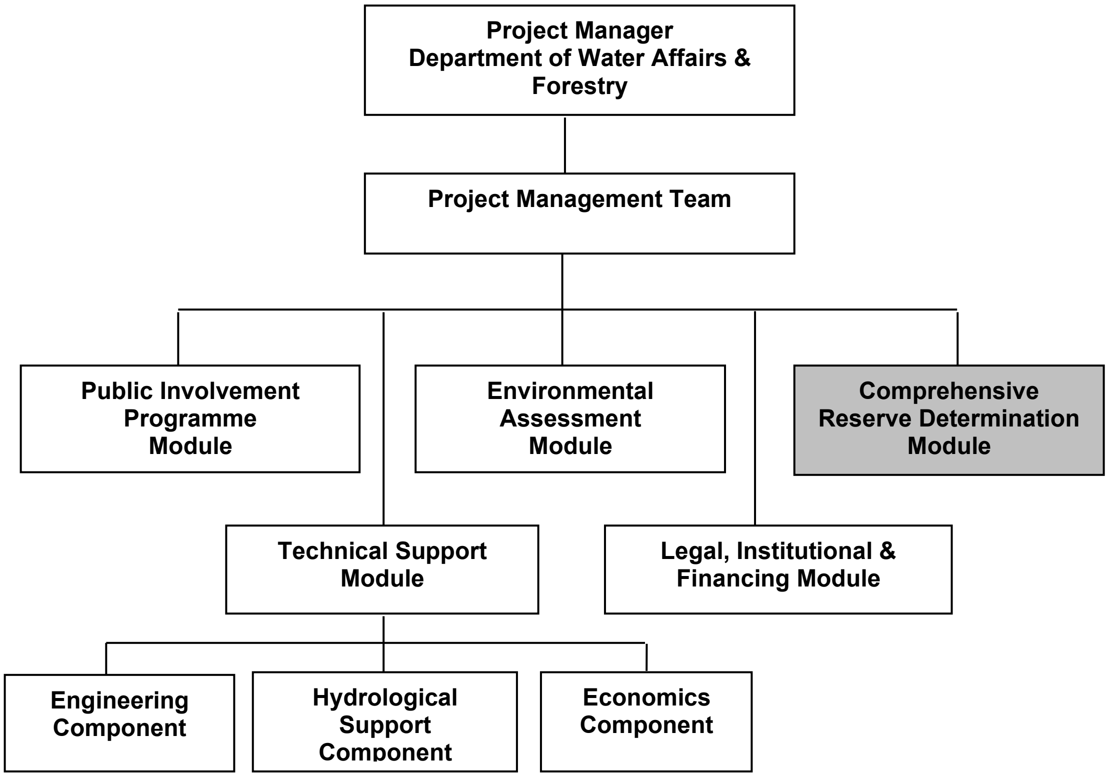
STRUCTURE OF DECISION SUPPORT PHASE



DEPARTMENT OF WATER AFFAIRS & FORESTRY
NATIONAL WATER RESOURCE PLANNING

THUKELA WATER PROJECT DECISION SUPPORT PHASE RESERVE DETERMINATION MODULE THUKELA SYSTEM ECOSPECS AND MONITORING REPORT

IWR SOURCE-TO-SEA **MARCH 2004**

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Chapter 3: Rivers: Study Area, Ecological classification and Recommended Reserve
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EXECUTIVE SUMMARY

BACKGROUND

The Reserve Determination Module (Module 3 of 5 for the Thukela Water Project Decision Support Phase) is designed, *inter alia*, to meet the requirements of the National Water Act No 36 of 1998. As such the study has been guided by three major parameters. These are:

- The objectives of Chapter 3 of the National Water Act No 36 of 1998 for a comprehensive Reserve Determination and the subsequent RDM protocols released by DWAF.
- The specific requirements of the Terms of Reference as supplied by Department of Water Affairs and Forestry (Tender WF7405).
- The needs of the Thukela Water Project and associated organs of the Department of Water Affairs and Forestry. These include broad based planning required to meet overall water resource management objectives in the catchment.

The purpose of this task is to formulate a monitoring programme for the Thukela catchment and to identify the Ecospecs that must be monitored. The purpose is not to document a manual for operating and maintaining a network and associated response programme. The objective of this task is to provide sufficient information to DWAF on the scope and potential cost of such a programme.

The approach mostly covers two phases of monitoring.

Baseline monitoring
The purpose of baseline monitoring is to:

- Provide sufficient representative ecological information on the resource to determine reference (usually natural) condition.
- Provide information to assess the PES.
- Contribute to the selection of appropriate indicators, setting of end points and TPCs (in terms of EC).
- Form the basis for the confidence with which the comparison between the expected (baseline) versus the long-term monitoring can be done.

Long-term monitoring
The purpose of long-term monitoring is to:

- Assess whether goals, objectives (set regarding the EC according to Ecospecs, end points and TPCs) are attained or not.

Note: Long-term monitoring is also referred to as detail or compliance monitoring. Although long-term monitoring should continue indefinitely, a 5 year period has been used for this study based purely on costing purposes.

PURPOSE OF THIS REPORT

The report consists largely of the results of a specialist meeting held on 6 - 8 October 2003 to determine the final Ecospecs and the associated monitoring programme. A proposed monitoring DSS has also been supplied.

PRINCIPLES OF THE MONITORING PROGRAMME

The monitoring programme is based on Adaptive Environmental Assessment and Management (AEAM) principles. This means that:

- There is a realisation that insufficient knowledge exist to accurately predict the outcome of particular management actions.
- There may be an under- or overprotection of the EC (Ecological Category), i.e. the desired state.
- The monitoring programme will be designed according to an iterative and feedback system (learning-by-doing-by-learning-by-doing) with specified TPCs (Thresholds of Potential Concern) and built in contingency procedures.
- Ecological specifications (referred to as ecospecs) will be formulated according to the available information and will be used as hypothesis as to their applicability and appropriateness.
- The first stage in defining ecological specifications will be broad and generic and will be improved and refined by providing more detail and insight that emanates from baseline surveys and repeated biomonitoring surveys.

Ecospecs
Ecospecs are derived from RQOs and are clear and measurable specifications of ecological attributes (e.g. water quality, flow, biological integrity) that define the Class and serve as an input to Resource Quality Objectives. Ecospecs refer explicitly and only to ecological information whereas RQOs include economic and social objectives.

Thresholds of Potential Concern (TPC)
TPCs provide a set of end points which describe the desired state in scientific detail and also provide the basis of a parsimonious programme of monitoring for a wide range of biodiversity indicators. TPCs are upper and lower levels along a continuum of change in selected environmental indicators. When this level is reached (or when modelling predicts it will be reached), it prompts an assessment of the causes of the extent of the change. The assessment provides the basis for deciding whether management action is needed or recalibrates the TPC. TPCs provide management with strategic goals or endpoints within which to manage the system. They form the basis of an inductive approach to adaptive management, as they are invariably hypotheses of limits of acceptable change in ecosystem structure, function and composition. As such their validity and appropriateness are always open to challenge and they must be adaptively modified as understanding and experience of the system being managed increases.

DECISION SUPPORT SYSTEM

The following assumptions are made prior to the Reserve monitoring DSS being implemented as described below:

- Both the Present Ecological State (PES) and Ecological Category (EC) derived from the Management Class have been specified in qualitative and quantitative terms. This is a product of the Ecological Reserve determination process.
- Water quantity and quality specifications for the EC are available.
- A particular Decision Support System has been followed to determine whether Compliance Reserve Monitoring is required.

The time scale and the scale of intensity that will be used for monitoring specific components will vary depending on the rate at which a component reacts to disturbance. However, wherever possible, monitoring should be directed towards direct measurement of biological end points. Drivers/primary determinants of the EC should be monitored and interpreted with reference to the biological/ecological end points.

APPROACH

The approach followed is based on previous work undertaken on, amongst others, the Mhlathuze River (IWR Environmental, 2003). Set templates have been provided which specialists complete during the specialist meetings. These facilitate the documentation of all the Ecospecs and the monitoring required to measure whether the Ecospecs are being achieved. The monitoring actions are described for the Baseline phase (one year) as well as for the Long-term phase. For each action required, the human resources to undertake the monitoring is described as well as the time. This is documented for each IFR site and for the estuary.

MONITORING REQUIREMENTS

The baseline monitoring requirements for 1 year and the long-term or detailed monitoring requirements for 5 years were provided during the 2-day monitoring specialist workshop (October 2003). The results were produced on Excel spreadsheet. A summary of the results is provided below.

River baseline monitoring (Time provided in 8 hour days)

Component	Sampling		Analysis		Reporting	
	Sp	Tech	Sp	Tech	Sp	Tech
IFR 1 total	5.7	12.2	5.85	7.5	4.3	1.5
IFR 2 total	5.7	12.2	5.85	7.5	4.3	0.5
IFR 4 total	5.7	16.2	5.85	11.5	4.3	0.5
IFR 9 total	5.7	2.2	3.35	1	1.3	0
IFR 15 total	5.7	6.2	5.85	1.5	3.3	0.5
IFR 16 total	5.7	8.2	3.35	13	2.3	0
IFR 3 total	5.7	12.7	5.85	8.55	4.8	0.5
IFR 5 total	5.7	16.2	5.85	13.5	4.3	0.5
IFR 7 total	5.7	16.2	5.85	11.5	4.3	0.5
IFR 8 total	5.7	2.2	3.35	1	1.3	0
IFR 10 total	5.7	12.2	5.85	7.5	4.3	0.5
IFR 11 total	5.7	2.2	3.35	1	1.3	0
IFR 13 total	5.7	16.2	5.85	11.5	4.3	0.5
IFR 14 total	5.7	2.2	3.35	1	1.3	0
GRAND TOTAL	**79.8**	**137.3**	**69.4**	**97.5**	**45.7**	**5.5**

River long-term monitoring (Time provided in 8 hour days)

Component	Sampling		Analysis		Reporting	
	Sp	Tech	Sp	Tech	Sp	Tech
IFR 1 total	8.5	45	5.6	43	7	0.5
IFR 2 total	8.5	35	6.1	31.5	8.5	0.5
IFR 4 total	8.5	35	6.1	51.5	8.5	0.5
IFR 15 total	4	5	3.5	0.5	4	0.5
IFR 16 total	4.5	40	2.6	41	4.5	0
IFR 3 total	8.5	47	6.1	41.5	8.5	0.5
IFR 5 total	8.5	35	6.1	51.5	10.5	0.5
IFR 7 total	8.5	45	6.1	41.5	8.5	0.5
IFR 10 total	4	32	3	30.5	6.5	0.5
IFR 11 total	4.5	5	3.6	1	2.5	16.6
IFR 13 total	4	50	2.5	50.5	7	0.5
IFR 14 total	4.5	5	3.6	1	2.5	16.6
GRAND TOTAL	**75.6**	**399**	**54.9**	**385.0**	**78.5**	**37.7**

Estuary

Estimated budget (in days) for baseline surveys for high priority components

Component	Sampling				Analysis				Reporting			
	Specialist		Tech		Specialist		Tech		Specialist		Tech	
	Closed	Other	Closed	Other	Closed	Other	Closed	Other	Closed	Other	Closed	Other
Birds	1	-	-	-	-	-	-	-	1	1	-	-
Fish	2	1	2	10	1	-	2	5	3	3	-	-
Invertebrates	-	3	4	21	10	-	3	17	5	9	-	-
Macrophytes	-	-	-	-	-	-	-	-	-	-	-	-
Microalgae	4	-	4	-	8	-	12	-	8	-	-	-
Water quality	2	-	2	-	Accredited laboratories				2	1	-	-
Hydrodynamics	-	-		14	-	-	-	4	-	1	-	1
Sediment	-	1	-	20	-	1	-	1 plus R 37 000	-	4	-	-
Total	**9**	**5**	**12**	**65**	**19**	**1**	**17**	**27 plus R 37 000**	**19**	**19**	**-**	**1**

Estimated budget (in days) for long-term monitoring programme per sampling year for high priority components

	Sampling		Analysis		Reporting	
	Specialist	Tech	Specialist	Tech	Specialist	Tech
Birds	-	-	-	-	2	-
Fish	3	5	-	2	1	-
Invertebrates	-	4 (+6)	10	3 (+6)	5 (+2)	-
Macrophytes	1	1	2	3	1	1
Microalgae	2 (+3)	2 (+3)	4 (+6)	6(+6)	8 (+ 4)	-
Water quality	1	3	Accredited laboratories		3	-
Hydrodynamics	-	14	-	4	1	1
Sediment	2	12	1	R 5000	2	-
Total	**9 (+3)**	**41 (+9)**	**17 (+6)**	**18 (+12) R 5000**	**23 (+6)**	**2**

* Resources in brackets only required if Varuna are absent from IFR sites where these were identified under the baseline study.

** Resources in brackets only required if an algal bloom occurs in the estuary.

IMPLEMENTATION OF THE RESERVE: HYDROLOGY MONITORING REQUIRED

There is a need to provide the natural triggers/cues, which are used to determine the Reserve requirements on a day-to-day (or month-to-month) basis. The natural trigger is used to determine the exceedence % point of the expected natural flow at any moment in time. Three possible methods have been identified, i.e. using gauged records, real time monthly simulation and real time daily simulation. Each of these has a range of advantages and disadvantages.

Either of the modelling approaches have distinct long-term advantages, which will be applicable not only to the Thukela system, but to every other catchment in the country. The main advantages are that the approach is flexible, has value beyond the immediate objectives of implementing the Reserve, and can be established as a generic methodology for any catchment.

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LIST OF ABBREVIATIONS AND ACRONYMS

AEAM	Adaptive Environmental Assessment and Management
Amsl	Above mean sea level
ASPT	Average Score Per Taxa
BIODSS	Biomonitoring Decision Support System
BMDSS	Baseline Monitoring Decision Support System
CEV	Chronic Effects Value
DO	Dissolved Oxygen
DSS	Decision Support System
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
Ecospecs	Ecological Specifications
EFR	Estuarine Flow Requirement
EHI	Estuarine Health Index
EIS	Ecological Importance and Sensitivity
ERA	Ecological Risk Assessment
EC	Ecological Category
FAII	Fish Assemblage Integrity Index
FS-R	Flow-Stressor Response
IFR	Instream Flow Requirement
LID	Large infrequent disturbances
MAR	Mean Annual Runoff
PES	Present Ecological State
PSD	Particle Size Distribution
RDM	Resource Directed Measures
RHP	River Health Programme
RQO	Resource Quality Objectives
RU	Resource Unit
RVI	Riparian Vegetation Index
SASS	South African Scoring System
SIC	Stones in Current
SOOC	Stones out of Current
Sp	Specialist
SRP	Soluble Reactive Phosphorus
Tech	Technician
TIN	Total Inorganic Nitrates
TOR	Terms of Reference
TPC	Threshold of Potential Concern
Traj	Trajectory
TWPDSP	Thukela Water Project Decision Support Phase
TWP	Thukela Water Project
WMS	Water Management System

1 INTRODUCTION AND BACKGROUND

1.1 BACKGROUND

The Reserve Determination Module (Module 3 of 5 for the Thukela Water Project Decision Support Phase (TWPDSP)) is designed, *inter alia*, to meet the requirements of the National Water Act No 36 of 1998. As such the study has been guided by three major parameters. These are:

- The objectives of Chapter 3 of the National Water Act No 36 of 1998 for a comprehensive Reserve Determination and the subsequent RDM protocols released by DWAF.
- The specific requirements of the Terms of Reference as supplied by Department of Water Affairs and Forestry (Tender WF7405).
- The needs of the Thukela Water Project and associated organs of the Department of Water Affairs and Forestry. These include broad based planning required to meet overall water resource management objectives in the catchment.

The Reserve Determination module involves quantification of the water resource required to meet objectives for the Thukela system under a series of scenarios which will be defined during the course of the study. This need for a scenario based approach was mooted so as to enable recommendations regarding water resource planning based on a suite of alternatives with regard to the needs of the Reserve and stipulated management classes for the Thukela system. Out of the Reserve Determination study information will be made available in a manner that will allow the Project Management Team (PMT) of the TWPDSP to make informed recommendations and decisions for the way forward. The specific objectives of this Reserve Determination Module are, therefore:

The work relevant to this report that has been undertaken at this stage is summarised as follows:

- Determine the Resource Units of the Thukela system, DWAF, 2003a.
- Determine the PES, the EIS and the ERC for each Resource Unit, DWAF, 2003b.
- Determine the IFR and quality requirements for different ERCs, DWAF, 2004a.
- Determine the Estuarine Flow Requirements, DWAF, 2004b.
- Determine additional operational scenarios and provide the ecological consequences, DWAF, 2004c.
- Recommend one flow scenario with its consequences to DWAF.

1.2 MONITORING APPROACH

1.2.1 Available Reserve information

The Thukela Reserve study is now nearing the end. A flow Scenario 9 has been selected as the recommended Reserve and the associated flow ecospecs and quality ecospecs will require monitoring.

1.2.2 Monitoring Programme

The monitoring programme for the flow and quality ecospecs include the collection of information to e.g. refine the Reserves, determine quantified RQOs and collect base line information to measure change against. Other monitoring components include compliance monitoring to determine whether the RQOs are being achieved, which includes the ecological specifications as well as 'use' monitoring (i.e. whether licence holders are complying with licence conditions, dams are being operated etc.). The monitoring of the catchment should therefore finally be an integrated programme and process which address more than just the ecological aspects.

This monitoring programme focuses on the monitoring of the ecospecs. Flow monitoring is limited to that required as part of the biota and habitat ecospecs monitoring, i.e. to link flow to biological response. It is acknowledged that compliance monitoring for flow will be required, as well as to operate the system linked to some trigger. This is however not included in the monitoring programme. The last chapter in the document illustrates possible means of hydrological monitoring linked to implementation of the Reserve.

1.2.3 Sequential steps

A detailed monitoring programme has been designed to address the monitoring needs. This will include monitoring to refine the Reserves where and if necessary, monitoring to refine the Ecological Specifications, baseline monitoring to measure change and compliance monitoring.

The steps followed during this task:

- All information regarding ecospecs already available for the recommended Reserve was collated.
- During a one-day meeting, a monitoring Decision Support System (DSS) was designed.
- During a two-day specialist meeting a monitoring programme was designed and costed to comply with the monitoring DSS.
- The information was documented in this report.

1.2.4 Output of this monitoring study

The detailed monitoring programme is supplied in the form of templates that provide the locality of monitoring sites, human resource, time, frequency of monitoring and cost as well as the component objectives/thresholds of potential concern. These forms can then be converted into a TOR and budget for the actual monitoring.

1.3 PURPOSE OF THIS REPORT

The report consists largely of the results of a specialist meeting held on 6 - 8 October 2003 to determine the final Ecospecs and the associated monitoring programme. A proposed monitoring DSS is also supplied.

The purpose of the report is the following:

- Document the approach followed.
- Provide the sequential actions undertaken during the specialist meetings to produce the results and to provide a detailed explanation of format of the report chapters for each IFR site in which the results are provided.
- Provide all the results for each IFR site and the estuary.
- Provide an estimated time cost of the monitoring programme.

1.4 STRUCTURE OF THE REPORT

Chapter one: Introduction and Background.
This chapter.

Chapter 2: Reserve monitoring programme
This chapter documents the information Dr. Kleynhans provided re principles of a monitoring programme, the definitions of ecospecs, Resource Quality Objective (RQOs) and Thresholds of Probable Concerns (TPCs) and the general approach of Adaptive Environmental Assessment and Management Principles.

Chapter 3: Rivers: Study Area, Ecological classification and Recommended Reserve
This chapter provides an overview of the study area, including the Resource Units and localities of the IFR sites.

Chapter 4: Monitoring DSS
This chapter describes the procedure within the decision making process to decide whether compliance monitoring is required, or a more synoptic biomonitoring approach according to the River Health Programme can be undertaken. The monitoring DSS which is applied to determine the actions required when TPCs are exceeded is documented.

Chapter 5: Monitoring programme: Rivers approach
The different approaches used during this study are described in this chapter. The approaches to determining the EC of each site as well as how the Ecospecs and TPCs were derived are discussed. Component monitoring approaches and monitoring requirements for baseline and long-term monitoring are explained.

Chapter 6-19: IFR sites
The monitoring results for each IFR site are provided in these chapters. This chapter summarises the process and the information generated during the specialist meeting per IFR site. Ecospecs and TPCs are generated for each IFR site and the baseline and long-term monitoring requirements for each component are dealt with. The structure of each chapter is the same for each site.

Chapter 20: Total cost for river monitoring
This chapter contains the integrated monitoring costs for all the sites for baseline and long-term monitoring.

Chapter 21: Thukela estuary ecospecs and monitoring programme
This chapter describes the study area, approach, monitoring requirements and costs for the estuary.

Chapter 22: Implementation of the Reserve: Hydrological monitoring required
This chapter provides different options of how to implement the Reserve by linking to natural triggers.

2 RESERVE MONITORING PROGRAMME

This chapter is a summary of a presentation by Dr. CJ Kleynhans.

2.1 BACKGROUND AND PURPOSE OF THE THUKELA MONITORING PROGRAMME

The purpose of this task is to formulate a monitoring programme for the Thukela catchment and to identify the Ecospecs that must be monitored. The purpose is not to document a manual for operating and maintaining a network and associated response programme. The objective of this task is to provide sufficient information to DWAF on the scope and potential cost of such a programme.

The approach mostly covers two phases of monitoring.

2.1.1 Baseline monitoring

The purpose of baseline monitoring is to:

- Provide sufficient representative ecological information on the resource to determine reference (usually natural) condition.
- Provide information to assess the PES.
- Contribute to the selection of appropriate indicators, setting of end points and TPCs (in terms of EC).
- Form the basis for the confidence with which the comparison between the expected (baseline) versus the long-term monitoring can be done.

2.1.2 Long-term monitoring

The purpose of long-term monitoring is to:
- Assess whether goals, objectives (set regarding the EC according to Ecospecs, end points and TPCs) are attained or not.

Note: Long-term monitoring is also referred to as detail or compliance monitoring. Although long-term monitoring should continue indefinitely, a 5 year period has been used for this study based purely on costing purposes.

2.2 PRINCIPLES OF THE MONITORING PROGRAMME

The programme should be based on Adaptive Environmental Assessment and Management (AEAM) principles (Sendzimir et al. 1999; Roux et al. 1999). This means that:

- There is a realisation that insufficient knowledge exist to accurately predict the outcome of particular management actions.
- This means that there may be an under- or overprotection of the EC, i.e. the desired state.
- The monitoring programme will be designed according to an iterative and feedback system (learning-by-doing-by-learning-by-doing) with specified TPCs (Thresholds of probable concern) and built in contingency procedures.
- Ecological specifications (referred to as ecospecs) will be formulated according to the available information and will be used as hypothesis as to their applicability and appropriateness.The first stage in defining ecological specifications will be broad and generic and will be improved and refined by providing more detail and insight that emanates from baseline surveys and repeated biomonitoring surveys.

The AEAM approach regards policy issues as testable hypothesis:

Policy as hypothesis → Management actions as tests → Evaluation

Integrated learning

Assessment

2.3 ECOLOGICAL SPECIFICATIONS

Ecological specifications were initially developed and specified in terms of the Resource Quality Objectives (RQOs) as per the Resource Directed Measures (RDM).

The purpose of RQOs is the following:

- To establish clear goals relating to the resource quality of the relevant water resources.
- Where resources for instance need a high level of protection, a strict set of objectives that will represent a low risk of damage, will be set.
- There is an implicit understanding that once the management class of a water resource has been decided, the objectives for protection of basic human needs and ecological integrity take precedence in cases where the objectives for other uses, or for impacts, may conflict with the requirements for protection.

The critical components of the RQOs are:

- Requirements for water quantity, stated as flow requirements for a river reach or estuary, and/or water level requirements for standing water or ground water, and/or requirements for groundwater level in order to maintain spring flow and base flow in rivers and other ecological features.
- Requirements for water quality (chemical, physical, and biological characteristics of the water).
- Requirements for habitat integrity, which encompass the physical structure of in-stream and riparian habitats, as well as the vegetation aspects.
- Requirements for biotic integrity that reflect the health, community structure and distribution of aquatic biota. The RQOs must further be quantifiable, measurable, verifiable, and enforceable and ensure protection of all components of the resource, which make up ecological integrity.

Ecospecs are derived from RQOs and are clear and measurable specifications of ecological attributes (e.g. water quality, flow, biological integrity) that define the Class and serve as an input to Resource Quality Objectives. Ecospecs refer explicitly and only to ecological information whereas RQOs include economic and social and political objectives.

2.4 THRESHOLDS OF POTENTIAL CONCERN (TPC)

TPCs provide a set of end points which describe the desired state in scientific detail and also provide the basis of a parsimonious programme of monitoring for a wide range of biodiversity indicators" (Rogers & Bestbier 1997).

TPCs are upper and lower levels along a continuum of change in selected environmental indicators. When this level is reached (or when modelling predicts it will be reached), it prompts an assessment of the causes of the extent of the change. The assessment provides the basis for deciding whether management action is needed or recalibrates the TPC. TPCs provide management with strategic goals or endpoints within which to manage the system. They form the basis of an inductive approach to adaptive management, as they are invariably hypotheses of limits of acceptable change in ecosystem structure, function and composition. As such their validity and appropriateness are always open to challenge and they must be adaptively modified as understanding and experience of the system being managed increases" (Rogers & Bestbier 1997).

Defining the TPCs requires the following: (Biggs in: Rogers & Bestbier 1997):

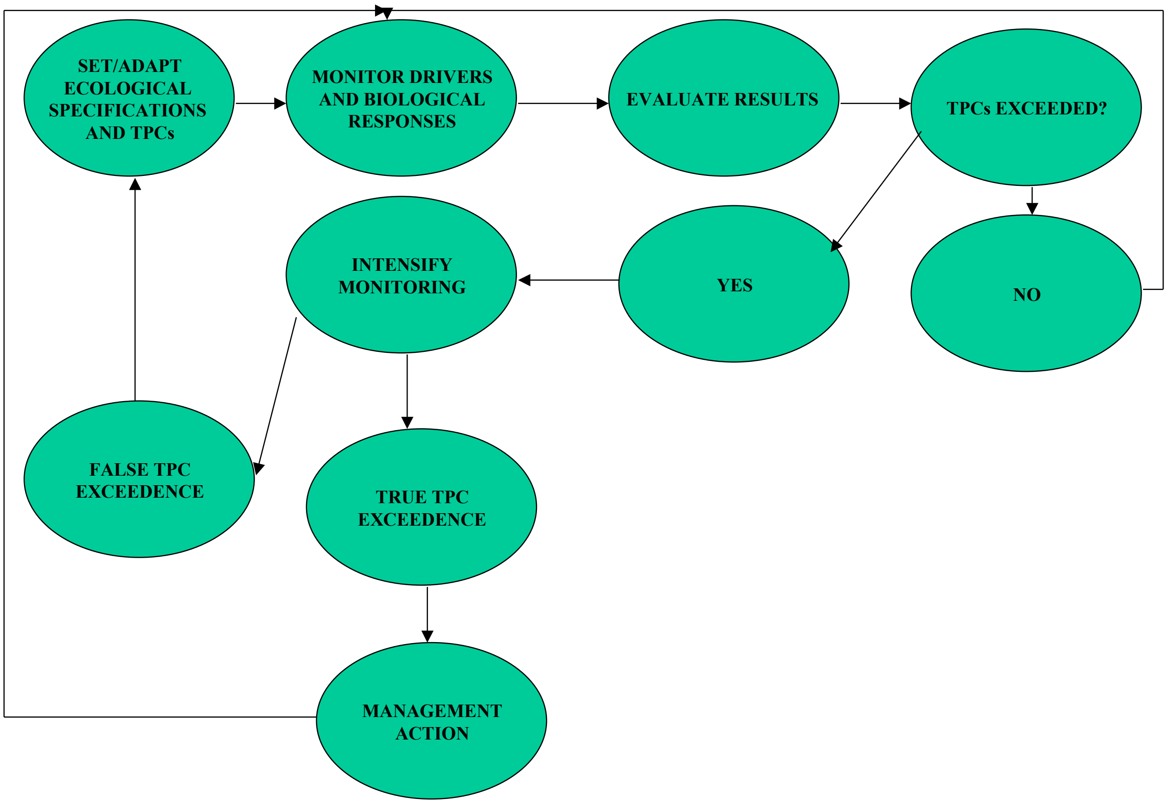
- Define the criteria (indicators) to be measured.
- Define spatial and temporal scales of measurement.
- Describe the sampling method and techniques.
- State the upper and lower levels of the TPC (end point).
- Provide the rationale for selection of the criteria and TPC.
- Prioritise and rationalise the derived TPCs to provide a manageable monitoring programme.

Indicator organisms can be used to define TPCs. The general attributes of good indicators (Noss 1990, Karr & Chu 1999) are the following:

- Sufficiently sensitive to provide an early warning of change.
- Widely applicable or distributed over an appropriate geographic range.
- Capable of providing continual assessment over a wide range of stress.
- Relatively independent of sample size.
- Easy and cost effective to measure.
- Enables discrimination between natural fluxes and anthropogenic stress.
- Relevant to ecologically significant phenomena and processes.

Figure 2.1 illustrates a monitoring DSS showing how TPCs are used within it.

Fig 2.1 An example of a monitoring DSS



2.5 COMPONENTS TO BE MONITORED

The time scale and the scale of intensity that will be used for monitoring specific components will vary depending on the rate at which a component reacts to disturbance. However, wherever possible, monitoring should be directed towards direct measurement of biological end points. Drivers/primary determinants of the EC should be monitored and interpreted with reference to the biological/ecological end points.

The following are candidates for inclusion in a generic monitoring approach:

- Drivers (primary determinants of EC).
  - Geomorphology.
  - Hydrology.
  - Water quality.
- Response variables.
  - Habitat integrity (site based and per Resource Unit or ecoregion context).
  - Biological integrity (specification of biological end points).
    - Macro invertebrates.
    - Riparian vegetation.

2.6 ECOLOGICAL RISK ASSESSMENT (ERA)

Biomonitoring results should be used to make management decisions. Ecological monitoring monitors the status and trend of indicators to determine whether the environment is improving, and is only marginally concerned about causal relationships.

The goal of ERA is to support environmental decision-making by estimating the nature and likelihood of prescribed effects of environmental stressor (Suter 2001). ERA estimates the effects of stressors on endpoint attributes to support decision-making (i.e. TPCs) and is devoted to elucidating causal relationships.

Biomonitoring programmes should therefore be planned within the framework of ERA, as this will allow important problems to be addressed and not only tracking indicators (i.e. it should go beyond the River Health Programme (RHP) objectives).

2.7 INTENSITY OF THE MONITORING

2.7.1 RHP vs compliance monitoring for the Ecological Reserve

It is important to distinguish between the RHP and compliance monitoring for the ecological Reserve.

The purpose of the RHP is to develop methods and generate information that can be used for National State of the Rivers reporting. As such the RHP (at least where it was applied in Mpumalanga) involved the rapid monitoring of the comparatively large number of sites distributed over the catchments of concern.

The nature of ***compliance monitoring*** (i.e. as for the ecological reserve) provide some indication that the intensity of sampling will be higher per site but that there will be less sites monitored as compared to the RHP approach. ***There would be more emphasis on quantifiable data and it is appropriate to eventually approach compliance monitoring from an ecological risk assessment perspective.***

Where possible, results from the RHP should be assessed for its usefulness in terms of compliance monitoring. This may mean that the main stem of a river will be subject to intensive monitoring due to the development taking place (e.g. impoundment), whereas tributaries in a comparatively un-impacted condition may only be subject to RHP-scale monitoring. However, if major changes in the tributary and its catchment take place, it would be prudent to intensify and concentrate monitoring in line with the nature of the disturbance. Contingency plans probably provide the best route to deal with such comparatively unexpected events.

2.7.2 Intensity of baseline collection phase

The purpose of baseline collection is to:

- Provide sufficient representative (e.g. according to RUs) ecological information on the resource to determine reference (usually natural) condition.
- Provide information to assess the PES and determine the EC.
- Contribute to the selection of appropriate indicators, setting of end points and TPCs (in terms of the EC).
- Forms the basis for the confidence with which the comparison between the expected (baseline) vs. compliance (detail) monitoring can be done.

The intensity of baseline collection will depend on:

- Availability of information, e.g. biota, hydrology, water quality, etc.
- Ecological importance and sensitivity (EIS; also linked to EC) – a high EIS would usually require a high intensity (smaller margin for error would be required).
- Biodiversity (species richness, ecosystems, etc.) – high overall complexity would imply higher intensity of baseline collection to be representative.
- Knowledge and insights into the response of various end point indicators to stressors (e.g. originating from modification of drivers)

2.7.3 Intensity of detail (long-term) monitoring phase

The purpose of detail monitoring is to assess the attainment or not of the goals and objectives set regarding the EC according to ecospecs, end points and TPCs. Monitoring at specified intervals to assess attainment will be required.

The initial intensity (number of sites, indicators per site and frequency) of the detail monitoring phase is mainly derived from and linked to the baseline monitoring: PES, EIS, and EC. Results of the monitoring may necessitate additional monitoring (secondary or response monitoring) where the level of a TPC is exceeded. This may indicate the necessity of more intensive monitoring involving different or additional indicators at specific sites (with their own levels of potential concern and end points) to test the validity of the TPC. This level of monitoring is probably dealt with most suitably in a contingency plan as part of an overall management plan.

2.8 DATA MANAGEMENT

Developing a new database specifically for Ecological Reserve monitoring should be carefully considered as there are many other databases (see below) in place:

- WMS (Water Management System – DWAF): eventually this should be the ideal system to use as database. It will however take some time to fully develop.
- River health programme (RHP): Rivers Database developed as part of the RHP programme. It is used by a somewhat limited number of people and is at this stage not always user friendly. It is however available and suitable for storage of data.

The shortcomings of the Rivers Database are receiving attention and it is therefore proposed that it be used for data management.

Eventually the monitoring information should be used within a decision support (management) system, e.g. rule-based system that provide the ability to store data, set ecospecs and TPCs and alert the user when limits are exceeded, and suggest appropriate reactions and actions.

3 STUDY AREA, ECOLOGICAL CLASSIFICATION AND RECOMMENDED RESERVE

3.1 STUDY AREA

3.1.1 Rivers

The study area has broadly been defined as the Thukela catchment. The main Thukela River is therefore addressed as well as the major portions of the most significant (from a hydrology viewpoint) tributaries:

- Thukela River from Rugged Glen Nature Reserve.
- Little Thukela River (Injasuthi) downstream from Wonder Valley base to the Thukela River confluence.
- Bushmans River (uMchezi) from Elands Park to the Thukela River confluence.
- Mooi River from the Little Mooi River confluence to the Thukela River confluence.
- Sundays River from the Newcastle/Ladysmith road bridge to the Thukela River confluence.
- Buffalo River (Mzinyathi) from the Utrecht/Osizweni road bridge to the Thukela River confluence.

The study area is illustrated in the Figures 3.1 and 3.2 which show the locality of the IFR sites and the Resource Units (indicated by capitals)

Fig 3.1 Upper Thukela Reserve study area

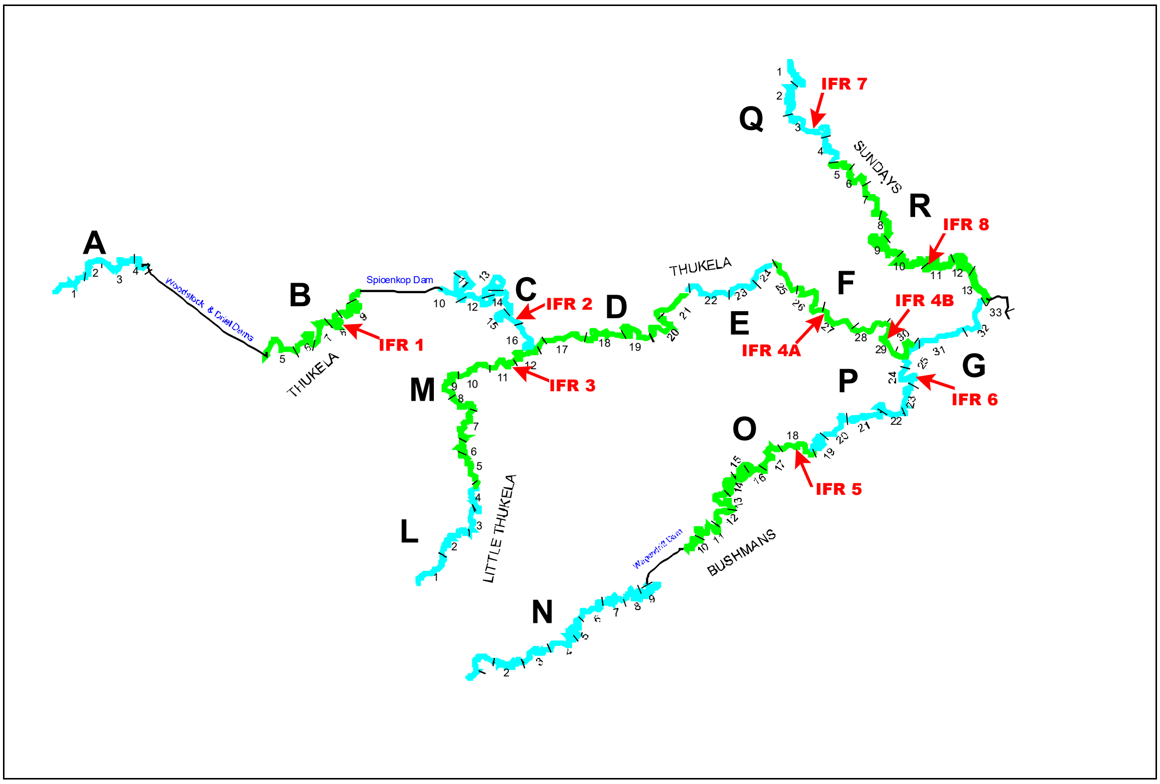
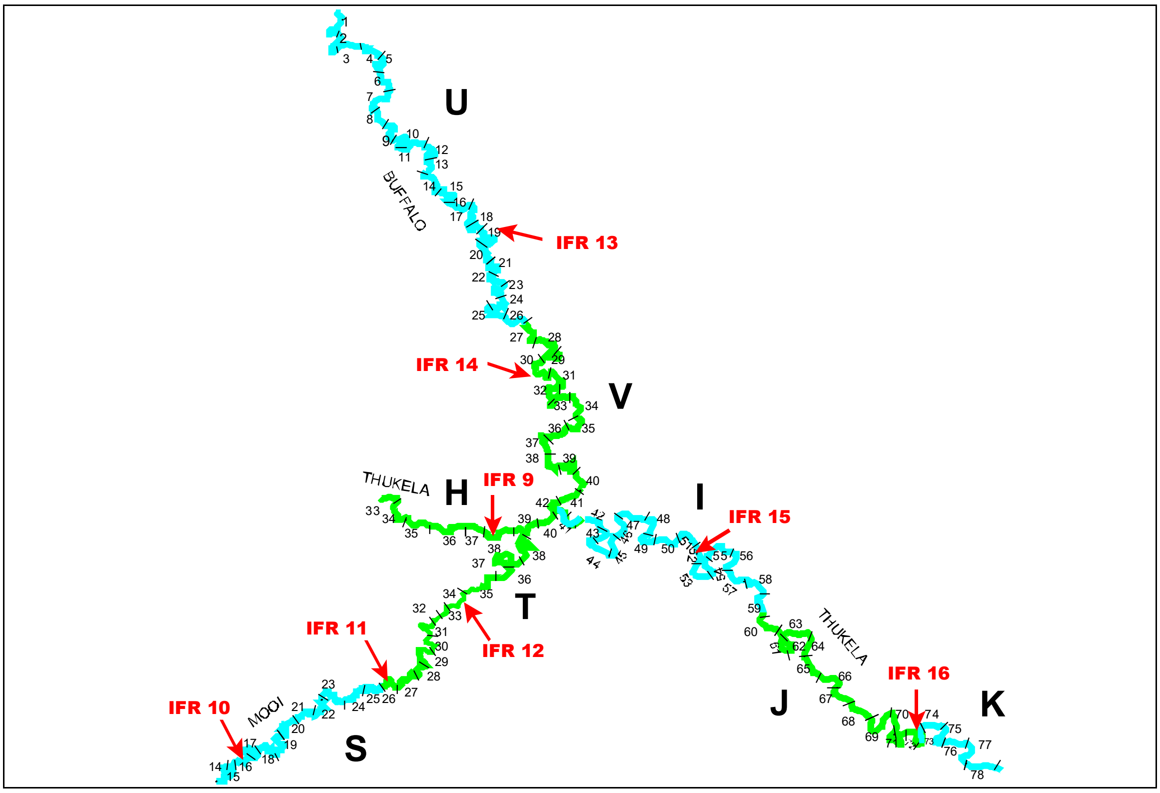


Fig 3.2 Lower Thukela Reserve study area



3.1.2 Estuary

The Thukela River estuary is situated approximately 100 km north of the city of Durban on the east coast of South Africa (29.22°S, 30.50°E; Figure 3.3). The estuary is one of only two examples of a large open river mouth estuarine system in South Africa, the other being the Orange River Estuary on the South African west coast.

Due to the high riverine runoff, the estuarine area of the Thukela River is small. The surface area of the estuary during low flow periods is approximately 0.6 km^2 and the estuary is about 6 km long.

Fig 3.3 Boundaries of the Thukela Estuary

The estuary is delineated by the geographical boundaries, as follows (Gauss Projection, Clarke 1880 Spheroid):

- **Downstream boundary:** The estuary mouth (31°29'56"E; 29°13'24"S).
- **Upstream boundary:** Approximately 6 km from mouth (31°26'23"E; 29°13'0"S).
- **Lateral boundaries:** 5 m contour above MSL along the banks.

3.2 ECOLOGICAL CLASSIFICATION

3.2.1 Rivers

The categories associated with Scenario 9 are supplied in the following tables. These categories are represented by the ecological endpoints (Ecospecs). Progress towards achievement of the ecospecs is measured to assess progress towards achievement or maintenance of the associated categories. In Chapter 6 to 20 the Ecospecs are defined in more detail for each component and category. All information regarding the Ecological Classification can be obtained in Report PDV000-00-10303.

Table 3.1 Ecological Classification – Thukela IFR sites

Legend

A	B	C	D	E
A/B	B/C	C/D	D/E	E/F
				F

IFR 1 (RU B)

COMPONENT	PES	LONGTERM (20 YEARS)	EC	SC9	ECOSPEC
Water quality	B/C	B/C	B/C	B/C	B/C
Geomorphology	D	D/E	D	C	D
Riparian vegetation	E	E/F	D	D	D
Fish	D	D	D	C/D	D
Aquatic invertebrates	D	D	D	C	D
Ecostatus	D	E	D	C/D	D

IFR 2 (RU C)

COMPONENT	PES	LONGTERM (20 YEARS)	EC	SC9	ECOSPEC
Water quality	B	B	B	B	B
Geomorphology	D	D/E	D	C/D	D
Riparian vegetation	C	C/D	C	B/C	C
Fish	C	C	C	B/C	C
Aquatic invertebrates	B/C	C/D	B/C	B	B/C
Ecostatus	C	C	C	B/C	C

IFR 4 (RU F)

COMPONENT	PES	LONGTERM (20 YEARS)	EC	SC9	ECOSPEC
Water quality	C	C	C	C	C
Geomorphology	B/C	B/C	B/C	B/C	B/C
Riparian vegetation	C	C/D	C	B/C	C
Fish	B?	B?	B?	C/D	C/D
Aquatic invertebrates	B/C	B/C	B	B/C	B/C
Ecostatus	B/C	B/C	B	B/C	B/C

IFR 9 (RU H)

COMPONENT	PES	LONGTERM (20 YEARS)	EC	SC9	ECOSPEC
Water quality	B/C	C	B/C	B/C	B/C
Geomorphology	D	D/E	D	D	D
Riparian vegetation	E	E/F	D	C	D
Fish	B	C	B	C	C
Aquatic invertebrates	C	C	C	A/B	C
Ecostatus	D	D/E	D	C	D

IFR 15 (RU I)

COMPONENT	PES	LONGTERM (20 YEARS)	EC	SC9	ECOSPEC
Water quality	B/C	C	B/C	B/C	B/C
Geomorphology	D	D/E	D	D	D
Riparian vegetation	C	C	C	B/C	C
Fish	E	E/F	D	C	D
Aquatic invertebrates	B	B	B	B	B
Ecostatus	C	C/D	C	C	C

IFR 16 (RU J)

COMPONENT	PES	LONGTERM (20 YEARS)	EC	SC9	ECOSPEC
Water quality	C	C/D	C	C	C
Geomorphology	C/D	D	C/D	C/D	C/D
Riparian vegetation	D	D/E	D	D	D
Fish	C	C	C	C	C
Aquatic invertebrates	C	C/D	C	C	C
Ecostatus	C/D	D	C/D	C/D	C/D

IFR 3 (RU M)

COMPONENT	PES	LONGTERM (20 YEARS)	EC	SC9	ECOSPEC
Water quality	B/C	B/C	B/C	B/C	B/C
Geomorphology	C/D	D	C/D	C/D	C/D
Riparian vegetation	D/E	E	D	D	D
Fish	C	C	C	D	D
Aquatic invertebrates	B/C	C	B/C	B/C	B/C
Ecostatus	C/D	D	C/D	C/D	C/D

IFR 5 (RU O)

COMPONENT	PES	LONGTERM (20 YEARS)	EC	SC9	ECOSPEC
Water quality	B/C	C	B/C	C	B/C
Geomorphology	B/C	C	B/C	B	B/C
Riparian vegetation	B/C	C	B/C	B	B/C
Fish	C	D	C	B/C	C
Aquatic invertebrates	C	C/D	C	A/B	C
Ecostatus	B/C	C	B/C	B	B/C

IFR 7 (RU Q)

COMPONENT	PES	LONGTERM (20 YEARS)	EC	SC9	ECOSPEC
Water quality	C	C/D	B/C	B/C	B/C
Geomorphology	B/C	C	B/C	B	B/C
Riparian vegetation	B/C	?	B/C	B/C	B/C
Fish	B	B	B	B	B
Aquatic invertebrates	C	C	C	C/D	C/D
Ecostatus	B/C	C	B/C	B/C	B/C

IFR 8 (RU R)

COMPONENT	PES	LONGTERM (20 YEARS)	EC	SC9	ECOSPEC
Water quality	C	C	C	C	C
Geomorphology	D	D	D	C/D	D
Riparian vegetation	E	E/F	D	D/E	D
Fish	C	C	C	C	C
Aquatic invertebrates	B/C	B/C	B/C	C	C
Ecostatus	D	D/E	D	D	D

IFR 10 (RU R)

COMPONENT	PES	LONGTERM (20 YEARS)	EC	SC9	ECOSPEC
Water quality	B	B	B	B	B
Geomorphology	C	C	C	C	C
Riparian vegetation	C/D	C/D	C/D	C/D	C/D
Fish	C	C	C	C/D	C/D
Aquatic invertebrates	B/C	B/C	B/C	C	C
Ecostatus	C	C	C	C	C

IFR 11 (RU T)

COMPONENT	PES	LONGTERM (20 YEARS)	EC	SC9	ECOSPEC
Water quality	A/B	A/B	A/B	A/B	A/B
Geomorphology	C	C	C	C	C
Riparian vegetation	C	C	C	C	C
Fish	B	B	B	B	B
Aquatic invertebrates	B	B	B	B	B
Ecostatus	B/C	B/C	B/C	B/C	B/C

IFR 13 (RU U)

COMPONENT	PES	LONGTERM (20 YEARS)	EC	SC9	ECOSPEC
Water quality	D	D/E	C	C	C
Geomorphology	D/E	D/E	D	D	D
Riparian vegetation	D/E	E	D	B/C	D
Fish	C	C/D	C	B/C	C
Aquatic invertebrates	C/D	D	C/D	B/C	C/D
Ecostatus	D	D/E	D	B/C	D

IFR 14 (RU V)

COMPONENT	PES	LONGTERM (20 YEARS)	EC	SC9	ECOSPEC
Water quality	C/D	C/D	C	C	C
Geomorphology	B/C	B/C	B/C	B/C	B/C
Riparian vegetation	B/C	C	B/C	B/C	B/C
Fish	C	C	C	B	C
Aquatic invertebrates	B	B	B	B	B
Ecostatus	B/C	B/C	B	B/C	B

3.2.2 Estuaries

Detail regarding the Ecological Classification is provided in report PBV000-00-10308, DWAF 2004b.

3.2.3 Reference Condition

The Reference Condition of the Thukela Estuary was set as its pristine state, i.e.:

- Receiving 100 % of natural Mean Annual Run-off (MAR) which was 3753.6 x 10^6 m^3.
- Sediment loading from the catchment representative of conditions prior to agricultural and industrial impacts.
- No wastewater discharges in the catchment e.g. waste discharges from the Mandini industrial area.
- No human disturbances in the estuary, e.g. those affecting bird populations.

3.2.4 Present Ecological Status

Present Ecological status (PES) is a measure of the health of a resource, based on a comparison between the Reference Condition and the Present State. An Estuarine Health Index (EHI) is used to determine the PES for estuaries. Scores allocated to the Thukela Estuary are listed in Table 3.2.

Table 3.2 Estuarine Health Score for the Thukela Estuary

Variable	Weight	Score	Weighted score
Hydrology	25	87	22
Hydrodynamics and mouth condition	25	80	20
Water quality	25	54	14
Physical habitat alteration	25	80	20
Habitat health score			**75**
Microalgae	20	65	13
Macrophytes	20	60	12
Invertebrates	20	60	12
Fish	20	70	14
Birds	20	70	14
Biotic health score			**65**
ESTUARINE HEALTH SCORE			70

The EHI score for the Thukela Estuary, based on its Present State, is 70, translating into a **Present Ecological Status of C+**.

3.2.5 Estuarine Importance (EI)

The Thukela Estuary was evaluated as being an **IMPORTANT** estuary. The Estuarine Importance scores allocated to the Thukela Estuary are listed in Table 3.3

Table 3.3 The Estuarine Importance scores of the Thukela Estuary

Criterion	Score	Weight	Weighted score
Estuary Size	80	15	12
Zonal Rarity Type	70	10	7
Habitat Diversity	50	25	13
Biodiversity Importance	76.5	25	19
Functional Importance	100	25	25
ESTUARINE IMPORTANCE SCORE			**76**

3.2.6 Recommended Ecological Category (EC)

The relationship between EHI Score, PES and EC for estuaries is listed in Table 3.4.

Table 3.4 Relationship between EHI Score, PES and EC for estuaries

EHI score	PES	Description	EC
91 – 100	A	Unmodified, natural	A
76 – 90	B	Largely natural with few modifications	B
61 – 75	C	Moderately modified	C
41 – 60	D	Largely modified	D
21 – 40	E	Highly degraded	-
0 – 20	F	Extremely degraded	-

The degree to which the minimum EC, based on its PES, needs to be modified depends on the importance of the estuary and modifying determinants, i.e. protected area status and desired protected area status.

Therefore, because the Thukela Estuary is rated IMPORTANT, the recommended EC should be '*Present Status Category (i.e. C) +1'*, which implies a Category B, or if not attainable a minimum of Category C.

Non-flow related anthropogenic activities (such as human disturbance of birds, over-fishing and removal of wetlands for agriculture) have had a significant influence on the present state of the estuary. As some of the changes caused by these activities would be difficult to reverse, the specialist team suggested that the Present State corresponding to a PES of C+ (i.e. upper range of the C category) be selected as the recommended EC, which still remains within the recommended guidelines for proposed for an 'Important' estuary.

Thus, the **recommended EC** for Thukela Estuary was set at a **Category C+** (Confidence = Medium).

3.3 RECOMMENDED RESERVE

The flow ecospecs for the recommended Reserve are provided as Appendix A in report PBV000-00-10308, DWAF 2004b. The results provided for IFR 16 serve as the estuary results.

4 MONITORING DECISION SUPPORT SYSTEM

4.1 BACKGROUND TO THE COMPLIANCE RESERVE MONITORING DSS

The following assumptions are made prior to the Reserve monitoring DSS being implemented as described below:

- Both the Present Ecological State (PES) and Ecological Category (EC) derived from the Management Class have been specified in qualitative and quantitative terms. This is a product of the Ecological Reserve determination process.
- Water quantity and quality specifications for the EC are available.
- A particular Decision Support System has been followed to determine whether Compliance Reserve Monitoring is required.

The following flow diagram (Figure 4.1) illustrates the DSS followed to establish a Baseline. Note that the same DSS will be followed whether Compliance Reserve Monitoring is required or Ecological Status Monitoring. It is assumed that the scope of the baseline requirements will differ depending which type of monitoring will be required. Compliance Reserve Monitoring is required when action have to be taken to implement the Reserve. Where this is not required, only Ecological Status Monitoring will be required.

Note that for the Thukela Reserve the following monitoring procedures were recommended in cases where Compliance Reserve Monitoring were not required:

- 3-yearly habitat integrity survey.
- 3-yearly biological survey following RHP approach and techniques for fish and invertebrates.

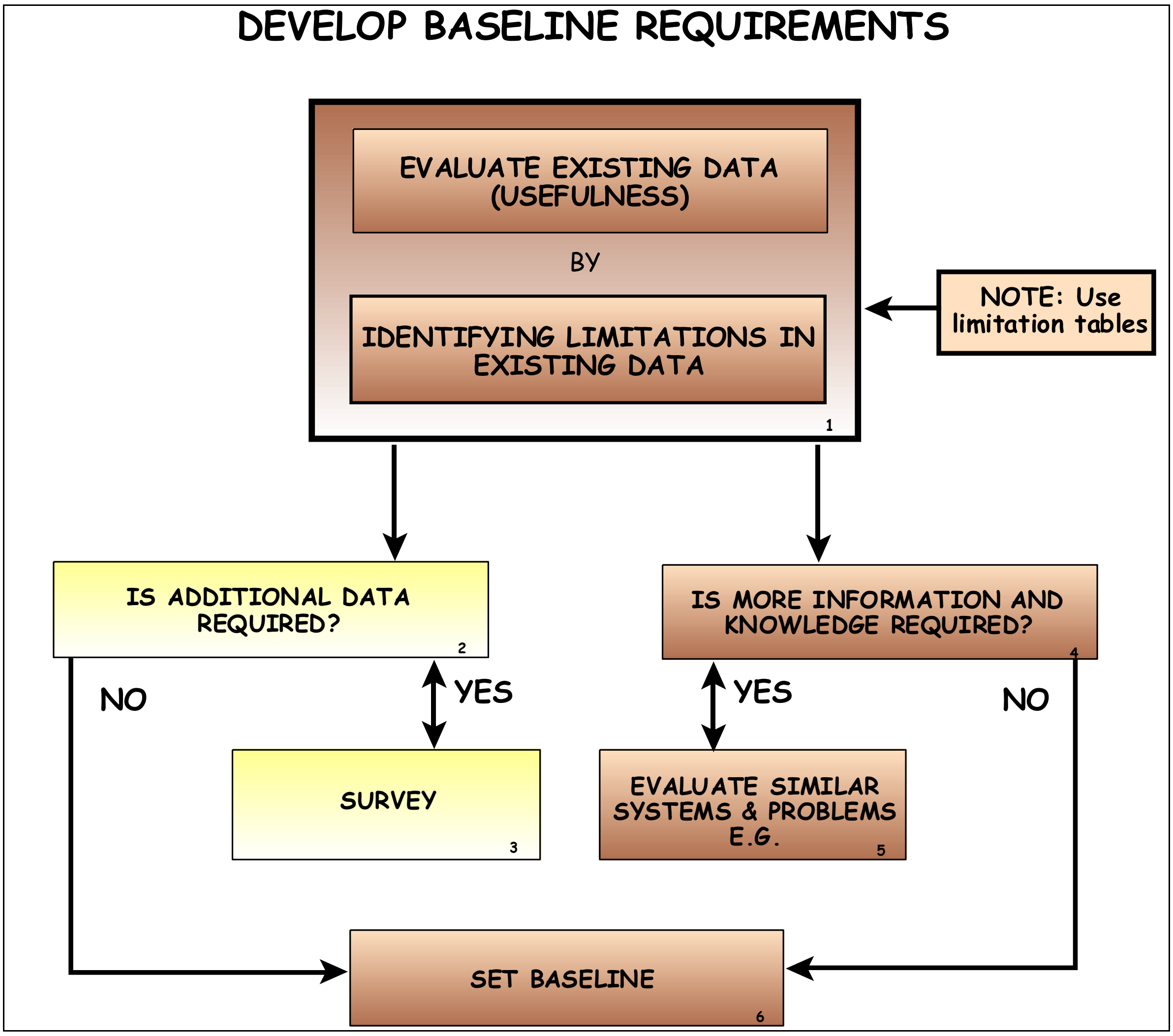
If, during the above surveys, TPCs are exceeded, the DSS as described in Figure 4.2, kicks in. Furthermore, if any major catchment changes or development changes take place, this should lead to the above monitoring to take place immediately, irrespective where one is in the 3-year cycle.

4.2 BASELINE MONITORING DECISION SUPPORT SYSTEM (BMDSS)

4.2.1 DSS illustrated by means of a flow diagram

The following flow diagram illustrates the process. Comments on each block are made according to the numbers within the blocks. Note that the baseline phase must have a fixed time period, preferably a year.

Fig 4.1 Develop baseline requirements



1: During the Reserve assessment process, existing information would be collated and some limited surveys undertaken. In some cases, this data would be sufficient, and the understanding would be sufficient to set the baseline without doing additional work. To determine whether the information is sufficient, one must identify the limitations in the data. To aid in identifying the limitations, a series of questions have been identified which have to be answered to assess whether limitations exist. Preliminary questions have been designed (see section 4.2.4) but require further 'unpacking', requires a DSS for each component, and probably require specific criteria. For example, if one of the questions is whether recent data is available, recent will have to be defined. It must also be noted that sufficient data could be available immediately after a Reserve determination to set the baseline. However, the more time that passes after the Reserve determination, the more unlikely it would be that the original acceptable baseline would suffice.

2, 3 & 6: If insufficient data is available, the necessary surveys must be undertaken. Once the information is available, the baseline can be set.

4,5 & 6: Even if sufficient data is available, understanding the data and interpreting the information is not necessarily possible. To address these problems, information on similar issues and situations should be obtained. If it is not possible to address the uncertainties, the approach of Adaptive Management can be followed. Following the Adaptive Management process, uncertainties could be addressed through the monitoring and used to refine the baseline and TPCs. This DSS has been further refined by CJ Kleynhans and modified during this specialist meeting.

4.2.2 Relevant considerations for drivers included in the BMDSS

Hydrology
Objective: To interpret changes in biological response components and to identify whether flow is a cause of change.

Water Quality
Objective: To interpret changes in biological response components and to identify whether the problems are point and/or diffuse source, or flow related.

Geomorphology
Objective: To interpret changes in biological response components and identify whether it is flow or non-flow related.

Habitat
Objective: To aid in interpreting changes in biological response components. To use as a TPC and substitute for detail biological information if necessary.

Riparian Zone (as a Driver)
Objective: If considered as a driver of biological response in the river itself – to interpret changes in biological response components within the riparian zone and identify whether changes are flow- or non-flow related.

4.2.3 Relevant Considerations for Biological Responses included in the BMDSS

Fish, Invertebrates and Riparian Vegetation
Objective: Specification of and assessment whether Ecological Reserve Category and Ecological Specifications are being attained.

4.2.4 Specifications for the components of the BMDSS

Purpose
To evaluate available data for usefulness in terms of appropriateness for baseline specifications: Identify limitations.

The following specifications constitute the BMDSS that should be followed to specify and establish a Baseline for compliance or ecological status monitoring.

Driver: Hydrology
Is there a lack of continuous hydrological monitoring close to monitoring sites?
Is there a lack of any continuous hydrological monitoring?
Is there low confidence in the hydrology?
Based on the above questions, how high is the suitability and confidence in the hydrological data for interpreting biological responses and determining if flow is a problem?

Very high
High
Moderate
Low

Driver: Water Quality
With respect to the following questions the term "Sufficient" relates to enough monitoring points in that section of river so as to provide an assessment of RC and PES, as required by the method (e.g. x number of data points in x number of years); and "Adequate" relating to the requirements of the method, which is in turn related to statistical power so as to determine trends and exceedences, if present (DWAF, 2002).

Are there sufficient water quality monitoring sites?
Is there a lack of water quality monitoring close to monitoring sites?
Is there adequate frequency of water quality monitoring?
Can you identify a critical parameter which can provide sufficient information in terms of biological response?
Are the appropriate parameters being monitored?
Is there sufficient understanding of point and/or diffuse source impacts?
Based on the above questions, how high is the suitability of and confidence in the water quality data for interpreting biological responses?

Very high
High
Moderate
Low

Driver: Geomorphology
Is there sufficient understanding of fluvial dynamics?
Is there sufficient knowledge of major catchment changes that influences morphology (e.g. dams, floods, droughts, agriculture etc)?
Is there a reasonable range and scale of aerial photographs available?
Has sufficient area/sites been covered by aerial photographs (video)?
Are you dependant on site-based data?
Can you discern between flow and non-flow related problems?
Based on the above questions, how high is the suitability of and confidence in the geomorphology data for interpreting biological responses?

Very high
High
Moderate
Low

Driver: Habitat
Is there a habitat model available? (If not, is a habitat model necessary and appropriate or will other tools such as multiple cross-sections, photos at different flows with depths measured etc suffice)
Is there a reasonable range of photographs available at different flows and of critical sites?
Is there sufficient understanding of the critical habitats and the response to change in flows?
Based on the above questions, how high is the suitability of and confidence in the habitat data for interpreting biological responses?

Very high
High
Moderate
Low

Driver: Riparian Zone
Is there sufficient understanding of the fluvial and riparian dynamics?
Is there sufficient knowledge of major catchment changes that influences morphology (e.g. dams, floods, droughts, agriculture etc.)?
Is there a reasonable range and scale of aerial photographs available?
Has sufficient area/sites been covered by aerial photographs and video?
Are you dependant on site-based data?
Can you discern between flow and non-flow related problems?
Based on the above questions, how high is the suitability of and confidence in the riparian vegetation data for interpreting biological responses?

Very high

High
Moderate
Low

Is habitat integrity /aerial video information available?

Biological Response: Fish
Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there info available from comparable neighbouring catchments)
Is recent information available?
Is sufficient understanding (egg intolerances, preferences and requirements), available?
Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Are there suitable interpretive indices available (FAII, H-FSR)?
Can you discern between flow and non-flow related problems?
Based on the above questions, how high is the suitability of and confidence in the fish data for interpreting biological responses to drivers?

Very high
High
Moderate
Low

Biological Response: Invertebrates
Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there info available from comparable neighbouring catchments)
Is recent information available?
Is sufficient understanding (egg intolerances, preferences and requirements), i.e. available?
Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)?
Are there suitable interpretive indices available? (SASS, H-FSR)
Can you discern between flow and non-flow related problems?
Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?

Very high
High
Moderate
Low

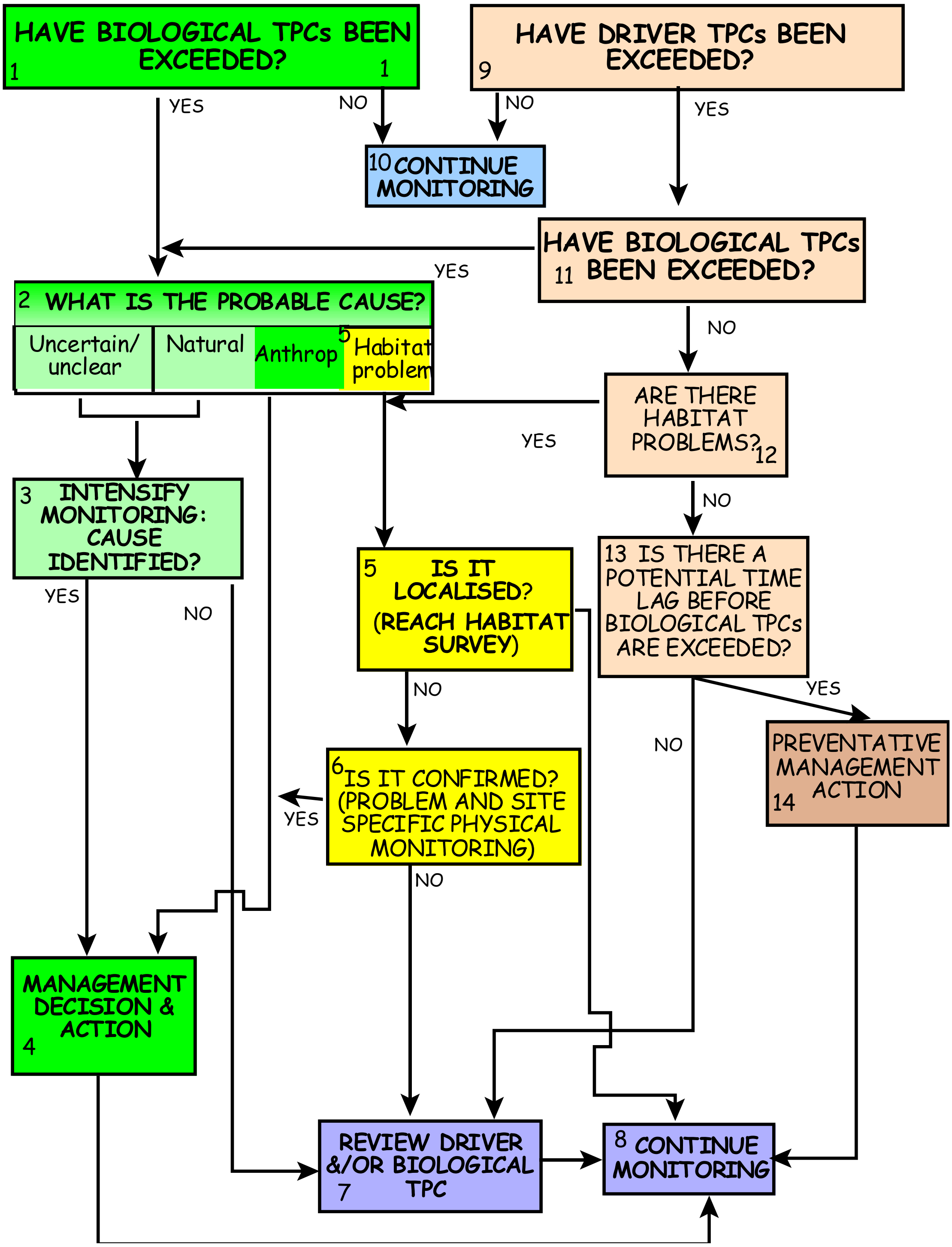
Biological Response: Riparian Vegetation
Is sufficient information (spatial and/or temporal and/or representative) available?
Are suitable key indicators available and to what degree are their flow requirements understood?
Is sufficient understanding of natural dynamics available?
Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Are there suitable interpretive indices available?
Can you discern between flow and non-flow related problems?
Based on the above questions, how high is the suitability of and confidence in the riparian vegetation data for interpreting biological responses to drivers?

Very high
High
Moderate
Low

4.3 COMPLIANCE BIOMONITORING DECISION SUPPORT SYSTEM (BIODSS) FOR ASSESSMENT AND MANAGEMENT OF MONITORING DATA AND INFORMATION

4.3.1 Process illustrated as a flow diagram

Fig 4.2 Compliance BIODSS



1, 9 & 10: During the long-term monitoring, TPCs have to be checked after each survey and analysis. If no TPCs have been exceeded, monitoring will continue.

1, 2, 3, 4, 5, 6, 7 & 8: If the biological TPCs have been exceeded, one has to determine *why*. It could potentially be one of the following:

- Anthropogenic: This could include human use for example such as removal of species, fishing mortality or harvesting. This could also include changes in the catchment due to increased human use. If it is identified as an anthropogenic problem, a management decision and action (Block 4) must be taken and monitoring continues.
- Uncertain/unclear: If this is the case, monitoring should be intensified, TPCs be reviewed and the cause established. If the cause is established, a management decision and action might be required and monitoring should continue. If the cause is not established, it is probably because the driver and or biological TPC is too conservative and must be reviewed. Monitoring must continue after the review.
- Natural: This refers to some natural biological problems such as disease and predation. The sequential process is the same as above.
- Habitat problem: A habitat problem could be evident such as embeddedness of rocks. It must then be established whether this is a localised problem by for example undertaking a reach habitat survey (Block 5). If it is localised, monitoring must continue. If it is not localised, the problem must be confirmed by site specific physical monitoring (Block 6). If it is confirmed, a management decision and action must be undertaken and monitoring must continue. If it is not confirmed, then the driver and or biological TPCs must be reviewed and monitoring must continue (Block 7 and 8).

9, 11, 12: If the driver TPCs have been exceeded, one then has to check whether the response components have reacted to this, i.e. whether the biological TPCs have been exceeded. If the biological TPCs have been exceeded, it must be determine why (block 2 on). If the biological TPCs have NOT been exceeded, one then has to check whether there are habitat problems (block 12). If there are habitat problems, the flow diagram from block 5 must be followed. If there are not habitat problems, one will have to evaluate whether this may be because the response components have not yet indicated a response (block 13). In this case, some preventative management action might be required, and monitoring will continue. If however, there is probably not a potential lag time, the biological or driver TPC must be reviewed and monitoring continued.

4.3.2 The process illustrated as a question-answer system

Assumptions and Principles
It is assumed that baseline requirements for drivers and biological components have been specified in terms of their relation with the EC.

The principles of the BIODSS are that normally the system would be followed by starting at step 1. This means that the drivers (at least some of them) would provide a continuous or regular flow of data that may require the immediate (i.e. outside the planned biomonitoring cycle) initiation of biomonitoring if driver TPCs is exceeded. However, if the driver TPCs are not exceeded, but monitoring of biological components according to the frequency and detail prescribed by the monitoring programme is done, these biological results must be assessed on their own by entering the BIODSS at step 2(b). (Note: The numbers below do not relate to the flow diagram, Figure 4.2).

1. Have Any of Driver TPCs been exceeded?

Hydrology TPCs
Water Quality TPCs
Geomorphology TPCs:
Instream Habitat TPCs (Instream IHI; Site and reach Habitat attributes – depth, velocity, cover):
Riparian zone TPCs

Yes: Go to 2(a)
No: If biological data is recent: Go to 2(b).
If not, Go to 3.

2(a). Initiate biomonitoring if biological data is not recent: Have Any Biological TPCs been exceeded?
2(b). Assess recent biological data: Have any biological TPCs been exceeded?

Fish TPCs (FAII, indicator spp. and groups):
Invertebrate TPCs (SASS, ASPT, indicator taxa):
Riparian Vegetation TPCs (RVI, indicator taxa):

Yes: Go to 4
No: Go to 3

3. CONTINUE MONITORING: REGULARLY REVIEW AND REFINE DRIVER AND BIOLOGICAL TPCs (INCLUDING BASELINE).

4. Is the Probable Cause of TPC exceedence due to human utilization (e.g., harvesting of fish, i.e. fishing mortality)?

Yes: Go to 13
No: Go to 5

5. Is the Probable Cause of TPC exceedence due to Natural causes?
Yes: Go to 3
No: Go to 6

6. Is the Probable Cause of TPC exceedence due to Water Quality Problems?
Yes: Go to 7
No: Go to 8

7. Are Water Quality problems non-flow related?
Go to 13
No: Go to 14

8. Is the Probable Cause of TPC exceedence due to Habitat Problems?
Yes: Go to 9
No: Go to 12

9. Are Habitat Problems Flow related?
Yes: Go to 13
No: Go to 10

10. Are Habitat Problems non-flow related?
Yes: Go to 13
No: Go to 11

11. Are Habitat Problems Localised?
Yes: Go to 15
No: Go to 16

12. Are the Origin of Biological Symptoms Uncertain/Not Clear?
Yes: Go to 14
No: Go to 4

13. MANAGEMENT DECISION AND ACTION: GO TO 3.

14. INTENSIFY MONITORING: HAVE THE CAUSE BEEN IDENTIFIED/ISOLATED?
Yes: Go to 4
No: Go to 14

15. UNDERTAKE DETAIL SITE HABITAT SURVEY: GO TO 4

16. UNDERTAKE REACH HABITAT SURVEY: GO TO 4

5 MONITORING PROGRAMME: RIVERS APPROACH

This chapter will describe and explain the information provided in Chapter 6 to 20.

5.1 FRAMEWORK FOR MONITORING THE PHYSICAL (GEOMORPHOLOGY) AND RIPARIAN VEGETATION COMPONENTS

The major drivers for the Thukela River catchment are Large Infrequent Disturbances (LIDs) (e.g. floods and droughts), which act on the physical template and the riparian vegetation. The characteristics of the large-scale physical template of the system are a function of constraints imposed by geology, tectonic history, climate and sea level change. Water is the major driver of the system and acts on the physical template to produce smaller scale morphology, for example; channel type, river morphology and associated riparian vegetation. An important consideration therefore for any monitoring is to find out where the site is located in time and space relative to the last LID. This will determine how the TPC is understood within a spatial and temporal context.

Because of the close link between geomorphology and riparian vegetation it was decided that the monitoring approaches should be combined. The following steps are suggested for each monitoring site (relevant for baseline and long-term monitoring):

- Analyses of the hydrological record to determine where the present day condition falls within the temporal range i.e. where are we within the broad scale hydrological record.
- Selection and analysis of the aerial photographic record to ensure a full range of conditions are considered within the broad scale hydrological record.
- Helicopter survey of the river (full survey where possible), digital video of the geomorphological reach together with the relevant monitoring site.
- Geomorphological and vegetation mapping of the reach using GIS overlays of the digital photography. This information will be compared with the new data as it becomes available via monitoring.
- Ground truthing of the maps.

5.2 HYDRAULICS APPROACH

Hydraulic and habitat conditions were determined as part of the ecological reserve study. This took place at different levels of intensity, ranging from the use of single and multiple rated cross-sectional profiles to habitat modelling based on numerous cross-sections encompassing a wider area at the sites. Confidence in the hydraulic characterisations varied at the IFR Sites, depending on the range of measured flows. The confidence and hydraulic/habitat descriptions could be improved during the baseline monitoring phase by collecting additional flow data and updating the hydraulic descriptions at “key” sites. These data may, if ever, only be required if a threshold of potential concern (TPC) were to be exceeded at some future date. The morphological structure of the site may however have changed during this period, and the refined hydraulics may be of limited use.

It will be more valuable to assess the available habitat when any TPC is exceeded. This may take the form of improving the confidence in the existing hydraulics, re-rating existing cross-sections, surveying and rating additional cross-sections, and even quantifying habitat availability over a wider area.

There is recognition, however, that some measure of habitat availability from the baseline period would benefit linking subsequent biotic response to changes in habitat. This would be best accomplished by assessing habitat conditions during biotic (particularly fish) surveys. This will involve the measurement of ranges in flow depth, velocity, cover and substrate at the sites, and is covered by the monitoring programme for fish.

For baseline monitoring, the accurate records of present day flows is required by means of establishing rated sections (Table 5.2). For follow-up monitoring, likely further hydraulic actions required to link biotic response to habitat availability is provided (Table 5.3).

Table 5.1 Further work and human resources during baseline period to establish local flow gauges

Site	Further work	Human Resource (Days) (days)				
		Survey		Analysis		Reporting
		Sp	Tech	Sp	Tech	Sp
1	Utilise upstream gauge. Repair crest plates at gauge (DWAF).		*			
2	Utilise upstream gauge at Spioenkop Dam (V1H057).					
4	Establish rated cross-section near IFR Site with surveyed cross-section, gauge plates and autodigital recorder.[2]	2	20	2		2
15	Establish rated cross-section near IFR Site with surveyed gauge plates and autodigital recorder.[2]	2	20	2		2
3	Establish rated cross-section near IFR Site with surveyed gauge plates and autodigital recorder.[2]	2	20	2		2
5	Establish rated cross-section near IFR Site with surveyed gauge plates and autodigital recorder.[2]	2	20	2		2
7	Utilise upstream gauge (V6H004).					
11	Utilise upstream gauge (V2H004).					
14	Establish rated cross-section upstream of IFR Site (Rorkes Drift?) with surveyed gauge plates and autodigital recorder.[2]	2	20	2		2

* Refer to DWAF hydrology.
[2] Estimate – to be referred to DWAF hydrology.

Table 5.2 Further work and human resources required at TPC exceedence

Site	Confidence evaluation	Further work	Human Resource				
			Survey		Analysis		Reporting
			Sp	Tech	Sp	Tech	Sp
1	Lowest measured flow $2.6m^3/s$. Low confidence for drought flows ($0.2m^3/s$).	Improve confidence by measuring low-flows (at approximately $0.1m^3/s$ and $1m^3/s$) and stage on existing cross-section. Survey and rate additional cross-section through pool type habitat.	1	4 (2 x 2)	1		0.5
2	Lowest measured flow $1.5m^3/s$. Medium confidence for drought flows ($0.5m^3/s$).	Improve confidence by measuring low-flows (at approximately $0.5m^3/s$) and stage on existing (3) cross-sections. Re-calibrate hydraulic habitat/DTM model.	1	4 (2 x 2)	1 5		0.5
4	Lowest measured flow $1.2m^3/s$ (4A) and $2.2m^3/s$ (4B). Medium/high confidence for drought flows ($1.7m^3/s$).	Re-calibrate hydraulic habitat/DTM model.			5		

Site	Confidence evaluation	Further work	Human Resource				
			Survey		Analysis		Reporting
			Sp	Tech	Sp	Tech	Sp
15	Lowest measured flow $18m^3/s$. Low confidence for drought flows ($2m^3/s$).	Improve confidence by measuring low-flows (at approximately $2m^3/s$ and $10m^3/s$). Flows to be related to photographic monitoring and the measurement of depths and velocities at the site.	1	4 (2 x 2)	1		0.5
3	Lowest measured flow $0.4m^3/s$. Medium/high confidence for drought flows ($0.2m^3/s$).	None.					
5	Lowest measured flow $0.9m^3/s$. Medium confidence for drought flows ($0.3m^3/s$).	Improve confidence by measuring low-flows (at approximately $0.2m^3/s$) and stage on existing (3) cross-sections. Re-calibrate hydraulic habitat/DTM model.	1	2 (2 x 1)	0.5 +5		0.25
7	Lowest measured flow $0.25m^3/s$. Medium confidence for drought flows ($0.11m^3/s$).	Improve confidence by measuring low-flows (at approximately $0.1m^3/s$ and $1m^3/s$) and stage on existing (4) cross-sections.	1	2 (2 x 2)	1		0.5
11	Lowest measured flow $1.0m^3/s$. Medium confidence for drought flows ($0.26m^3/s$).	Improve confidence by measuring low-flow (at approximately $0.1m^3/s$) and stages on existing (3) cross-sections. Re-calibrate hydraulic habitat/DTM model.	1	2 (2 x 1)	0.5 +5		0.25
14	Lowest measured flow $0.6m^3/s$. Medium/high confidence for drought flows ($0.41m^3/s$).	Re-calibrate hydraulic habitat/DTM model.			5		

Note:
Reporting – Update existing hydraulics report for Thukela River system
DTM – Digital terrain model
(2 x 2) – 2 days x 2 technicians

To determine whether additional habitat data is required for monitoring at the key IFR sites, the following questions were put to the instream specialists. The results are provided in Table 5.4.

1. Is there a habitat model? If not, is a habitat model necessary or will alternate tools suffice (such as multiple rated cross-sections and/or photographs at different flows corresponding to measured depths)?
2. Is there a reasonable range of photographs of critical habitats at different flows?
3. Is there sufficient assessment of the critical habitat availability at different flows?
4. Based on the above questions (1 - 3), what is the suitability of and confidence in the habitat data for interpreting biological response? (low, moderate, high).

Table 5.3 Habitat data

Site	Component	Question			
		1	2	3	4
1	Fish/inverts	No/yes	No	No	Moderate/low
2	Fish/inverts	Yes	No	No	Moderate
4	Fish Invertebrates	Yes	Yes[1]	Yes[1]	Moderate/high High
15	Fish/inverts	No/yes	No	No	Low/moderate
3	Fish Invertebrates	No/yes No/yes	Yes Yes	Yes No	High Low/moderate
5	Fish/inverts	Yes	Yes	Yes	Moderate/high
7	Fish/inverts	No/yes	Yes	Yes	Moderate/high
11	Fish/inverts	Yes	Yes	Yes	Moderate/high
14	Fish/inverts	Yes	Yes	Yes	Moderate/high

1 Close-up photographs of critical habitat not well represented.

5.3 WATER QUALITY APPROACH

Boundaries of categories (e.g. the value distinguishing the category B quality objectives) are defined by the quality ecospecs as determined during the Thukela Reserve Determination study: Water quality. Monitoring is currently conducted as part of the DWAF monitoring network. Additions to current monitoring, e.g. chl-a, DO, turbidity and temperature, are recommended. Although temperature is included in methods only when a temperature impact is expected (e.g. thermal pollution or downstream of a dam), it is recommended that temperature be taken during routine monitoring as no additional manpower days are required. Current monitoring is conducted more frequently than required by the monitoring programme at some sites, while the initiation of monitoring is recommended at selected sites.

It is important to note the data record used for assessments, particularly if additional or more frequent monitoring is required at this site.

Note the distinction between a TPC and a threshold of *real* concern, i.e. the boundary value between categories. For example, the value defining the upper boundary of the good category for Soluble Reactive Phosphorus (SRP) is $\leq$ 0.025 mg/L soluble reactive phosphorous. This is then the threshold of *real* concern, and implies that when this value is exceeded SRP will be in a fair category. The TPC will then be when *50% of the data record* reaches that value, i.e. most of the data is tending toward exceeding the category, and action may be required. A different approach is followed for the estuary, with values given instead of ranges, due to the management requirements for estuaries (Taljaard, *pers. comm.*).

At some IFR sites the recommendation has been to monitor toxic substances. Since there are a multitude of potential toxic substances, judgement regarding which toxic substances to monitor should be made based on land-use and potential water quality impacts.

Quality Ecospecs are listed in Section 5 of the Thukela Water Quality Report per IFR site, DWAF, 2004d and categories defined in DWAF, 2002 and are applicable to all sites.

5.4 ECOSPECS AND TPCs

For definitions and explanations of Ecospecs and TPCs, see Chapter 2.

Ecospecs and TPCs were generated during the two-day specialist monitoring meeting during October 2003. The results were produced on an Excel spreadsheet which is copied into this section. The complete Excel spreadsheets are available electronically.

An example of the table is provided in Table 5.4. Column 1 lists the Ecospecs. Column 2 lists the associated TPCs which are linked by the same number to the Ecospecs.

Table 5.4 Ecospecs and TPCs

Ecospecs	TPCs
1. All species expected for a D category should be present: *Labeobarbus natalensis, Labeo rubromaculatus, Barbus anoplus*. (I.e. viable populations). Fish health and condition should be moderate to good.	1.Absence of any of the species.
2. All year classes of all species represented.	2. Absence or drop in abundance of any year class (+ measurable increase in siltation).
3. Maintain critical stress level below 6.0 to facilitate breeding success and year round survival of *Labeobarbus natalensis:* FD = 3 FS = 3 SD = 4 SS = 3. HABITAT SUITABILITY RATING: Breeding = 3 Survival/Abundance = 4 Cover = 4 Health = 5 Water quality = 5	3. Drop in abundance of any of the flow-depth and cover classes (which would relate to increased stress).

5.5 ADDITIONAL BASELINE REQUIREMENTS

During a Reserve study, information is collated which serve as baseline information. However, due to the constraints of Reserve studies, sufficient information cannot often be collated. The Thukela specialists therefore used the analysis described in 4.2.4 to answer the questions and provide motivations for collecting additional baseline information.

5.6 MONITORING REQUIREMENTS

The baseline monitoring requirements for 1 year and the long-term or detailed monitoring requirements for 5 years were provided during the 1 day monitoring specialist workshop (October 2003).

Note: The 5-year period is only used for budget purposes. It is accepted that long-term monitoring should continue indefinitely, although the scope might be further minimized after the initial first couple of years. The baseline monitoring tables for all sites refer to the total for one year of monitoring and the long-term monitoring tables for all sites refer to the total for 5 years of monitoring.

The results were produced on Excel spreadsheet which is copied into this section. The complete Excel spreadsheets are available electronically. An example is provided in Table 5.5.

5.6.1 Baseline monitoring

Column 1: Action: The actions required are listed in this section.
Column 2: Ecospec/TPC: The numbers listed links the action to the Ecospec/TPC, i.e. column 1 and 2 in Table 5.4.
Column 3: Season: Lists the season in which the action should take place.
Column 4: Frequency: This provides the frequency and season.
Column 5 & 6: Survey: Sp and Tech: Provides the man-hour days which is required to perform associated surveys for the action. The time is split between the use of a specialist and a technician.
Column 7: Analysis: Sp and Tech. Provides the time required for either the specialist or technician to undertake the analysis of data collated during surveys.
Column 8: Provides the time for the specialist to report on the analysis.

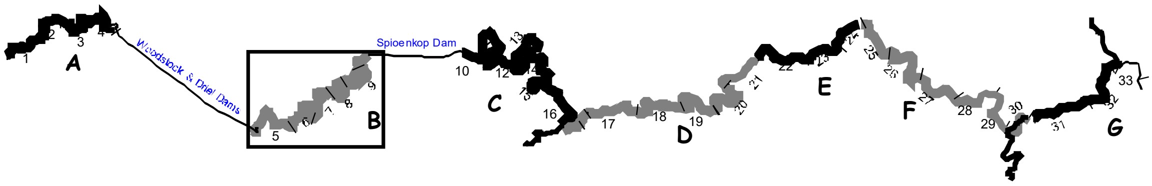
Table 5.5 Baseline and long-term monitoring requirements

<table>
<tr><th colspan="10">BASELINE</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Fish survey at IFR site (and section of river reach).</td><td rowspan="5">1,2,3</td><td rowspan="5">Low flow season</td><td rowspan="5">1 Low flow season</td><td rowspan="5">1</td><td rowspan="5">1</td><td rowspan="5">0.5</td><td rowspan="5"></td><td rowspan="5">0.5</td><td rowspan="5"></td></tr>
<tr><td>Seine sampling (10 efforts distributed over the section) and electro fishing (>40 minutes effort, 2 passes). Sampling quantified (CPUE, etc.)</td></tr>
<tr><td>Determine length frequencies, age classes.</td></tr>
<tr><td>Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.</td></tr>
<tr><td>Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).</td></tr>
<tr><th colspan="10">LONG-TERM (5YR)</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Fish survey at IFR site (and section of river reach).</td><td rowspan="5">1, 2, 3</td><td rowspan="5">Low flow season</td><td rowspan="5">1 low flow season for 3 years during the baseline phase</td><td rowspan="5">0</td><td rowspan="5">2</td><td rowspan="5">0.5</td><td rowspan="5"></td><td rowspan="5">0.5</td><td rowspan="5"></td></tr>
<tr><td>Seine sampling (and electro fishing (>40 minutes effort and/or 2 passes). Sampling quantified (CPUE, etc.).</td></tr>
<tr><td>Determine length frequencies, age classes.</td></tr>
<tr><td>Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.</td></tr>
<tr><td>Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming)</td></tr>
</table>

5.6.2 Long term monitoring

This information is included in the spreadsheet in the same format as for baseline monitoring. All information is however provided for 5 years after baseline collection. It must be noted that long-term monitoring was not specified for all the sites. Key sites were selected and if, during monitoring, specific problems with the suitability of the sites or associated TPCs are noted, the baseline information will be available to undertake monitoring at the sites not specified in this document. Sites that were left out or at which only come components are measured are IFR 9, IFR 8, IFR10, and IFR 13.

6 RU B. IFR 1. BERGVILLE (UPPER THUKELA RIVER)



6.1 SITE DESCRIPTION

The site is situated at the start of the gorge downstream of Bergville. The left bank is bordered by agricultural lands and forms very steep grassed edge to the instream channel. The right bank is adjacent to a hill where informal grazing takes place. Exotic mixed with indigenous vegetation occurs on this bank. Backwaters and a medium flow channel occur on the right side of the channel. The channel is alluvial with pool/riffle morphology. The bed material consists of gravel and cobble.

The site is characterised by unseasonal releases as Driel Dam is often overtopped and unnatural high flows therefore often occurs.

6.2 ECOSPECS AND TPCs

Table 6.1 The various Ecospecs and related TPCs for each component – IFR 1

ECOSPECS	TPCs
Geomorphology	
1. To maintain the trajectory and relative location, composition and structure of morphological units within a reach (within a resource unit).	1. A significant change in the trajectory and relative location, composition and structure of morphological units within a reach (within a geomorphological zone).
Riparian vegetation	
1. To maintain the trajectory and relative location, extent, composition and structure of riparian and marginal vegetation on morphological units within a reach (within a resource unit).	1. A significant change in the trajectory of riparian and marginal vegetation on morphological units within a reach (within a resource unit).
Water quality	
1. Inorganic salts (magnesium sulphate, magnesium chloride, sodium sulphate, sodium chloride, calcium sulphate, calcium chloride) or salt ions	1. 95%ile of data must not exceed the category A upper boundary as defined by the quality ecospecs.
2. Nutrients: SRP (synonymous with PO^4 or orthophosphate)	2. 50%ile of data must not exceed the category C upper boundary as defined by the quality ecospecs.
3. Nutrients: TIN	3. 50%ile of data must not exceed the category A/B upper boundary as defined by the quality ecospecs.
4. System variables: pH, DO, temperature	4. 95%ile of data must not exceed the category B upper boundary as defined by the quality ecospecs.
5. System variables: turbidity / SS	5. A TPC cannot be provided as no data or method is currently available. Noted as developmental issue.
6. Algal abundance (chl-a)	6. Concentration must not exceed the quality ecospec for periphyton.
7. In-stream toxicity (minimum is *Daphnia*, fish and algal tests)	7. Any indication of toxicity as shown by any single test as specified in the ecospecs column (i.e. *Daphnia*, fish or algal test).
Fish	
1. All species expected for a D category should be present: *Labeobarbus natalensis, Labeo rubromaculatus, Barbus anoplus*. (I.e. viable populations). Fish health and condition should be moderate to good.	1.Absence of any of the species.
2. All year classes of all species represented.	2. Absence or drop in abundance of any year class (+ measurable increase in siltation). Note: Increase in siltation should be measured through water quality or geomorphology.

ECOSPECS	TPCs
3. Maintain critical stress level below 6.0 to facilitate breeding success and year round survival of *Labeobarbus natalensis:* FD = 3 FS = 3 SD = 4 SS = 3. HABITAT SUITABILITY RATING: Breeding = 3 Survival/Abundance = 4 Cover = 4 Health = 5 Water quality = 5	3. Drop in abundance of any of the flow-depth and cover classes (which would relate to increased stress).
Aquatic invertebrates	
1. To ensure that the SASS5 scores and ASPT values occur in the set range (except after major floods and during droughts). Stones biotope: SASS >110 ASPT >6.5 (in winter) No of taxa 17. Vegetation biotope: SASS >25, ASPT >5.5 (in winter) No of taxa 4.	1. Stones biotope: SASS5 score <120 and ASPT <6.5 in winter. Vegetation biotope: SASS5 score <30 and ASPT <5.5 in winter.
2. Ensure that no invertebrate taxon consistently dominates the fauna.	2. When any taxon has an abundance of >100 while all other taxa are <10, for two consecutive surveys.
3. Maintain presence of Baetidae in stones biotope.	3. Baetidae occur in an abundance <10 for two consecutive surveys.
4. Maintain suitable conditions for filter feeding organisms such as Hydropsychidae and Simuliidae.	4. Hydropsychidae or Simuliidae occur at abundance <10 for two consecutive surveys.
5. Maintain connectivity with marginal vegetation biotope.	5. Leptoceridae absent from entire sample on two consecutive surveys.
6. Flow regime to maintain the current speeds for rheophilic species.	6. Abundance of rheophilic taxa in total <10 individuals.
7. Flow regime to maintain the current diversity of biotopes.	7. Either SIC, SOOC or Marginal Vegetation biotopes are lost to invertebrates.

6.3 ANALYSIS OF LIMITATIONS IN AVAILABLE INFORMATION

6.3.1 Geomorphology

Note: Geomorphology information provided is applicable to all the sites listed below and will not be repeated in the other chapters.

IFR SITES:
- Thukela River - 1, 2, 4 and a combination of 15 & 16
- Little Thukela River - 3
- Bushmans River - 5
- Sundays River - 7
- Mooi River - combination of 10 & 11
- Buffalo River - combination of 13 & 14

The suitability of and confidence in the available geomorphological data for interpreting biological response is **moderate** to **high.** Limitations in geomorphological data are the result of the following factors:

- At present geomorphological data are largely site-based. To overcome this shortcoming, helicopter surveys utilising a digital video camera should be done for a representative area around (upstream and downstream) the IFR site.
- Geomorphological changes may occur over long period (>50 years). These may be difficult to identify in the short-term. To identify these potential changes, geomorphological mapping needs to be executed. This can be done utilising digital video and still photography from the helicopter survey and through utilising GIS.
- An understanding of the location of the IFR site in relation to the trajectory of change (hydrological and geomorphological) has not been achieved. This can be achieved through utilising and interpreting suitable data and records (hydrological, aerial photographs etc.). For example, the analysis of aerial photographs should be done in conjunction with the long-term hydrological record.

6.3.2 Riparian vegetation

Riparian vegetation is applicable to all the IFR sites and will not be repeated in each chapter.

Applicable to IFR Sites: 1,2,3,4,5,7,11,14,16

The suitability of existing riparian vegetation data for interpreting biological responses is moderate for the following reasons:

- At present the riparian vegetation data are largely site based as this was required for the purposes of the Ecological Reserve Assessment. To overcome this limitation it is necessary to supplement this data with aerial photographical interpretations, vegetation mapping and by undertaking additional low level helicopter videos for baseline and monitoring surveys
- Understanding of the riparian dynamics is dependant on establishing where the site is located in time and space relative to the last LID. It is therefore important to establish this by initially interpreting the hydrological data and available aerial photographs. This will be required for each of the sites.
- A range of aerial photographs are available for monitoring purposes, however, it is necessary that a similar scale be used for comparative purposes. It is recommended that a low level digital video is undertaken for baseline and follow-up surveys to allow for the comparison of features, from digital still photographs, to assist with detecting and understanding potential vegetation changes.
- A dependence does on site based data as it will be necessary to refine the assessment by ground truthing to identify the species composition and structural classes of the riparian and marginal vegetation on geomorphological units.
- Non-flow related impacts are likely to complicate the understanding of identified changes in riparian vegetation. This is particularly true for those impacts which have an influence on species composition and structure such as grazing, browsing and vegetation removal. The nature and extent of these impacts vary from site to site and will only be understood with the assistance of ground based observations and truthing.

6.3.3 Water quality

Conditions to be maintained, therefore water quality to be a B/C category. RU B contains two QRUs, but combined due to data limitations. SASS score = D, due to habitat and filamentous algae, so recommend monitoring Chl-A. As downstream of Driel barrage, temperature, DO and turbidity should be monitored.

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
No, as two QRUs combined for the RU as only 1 monitoring point.

Is recent information available?
No

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Yes

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Yes. Nutrients, specifically SRP and chl-a.

Are there suitable interpretive indices available? (SASS, H-FSR)
No. Include chl-a (due to filamentous algae), turbidity, DO and temperature (as downstream of Driel barrage).

Can you discern between flow and non-flow related problems?
Yes

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate

6.3.4 Fish

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Information is not sufficient at all and will have to be obtained through the baseline survey.

Is recent information available?
No recent information.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding of the requirements of the only species actually known to be present is generally sufficient.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Interpretive knowledge on the habitat-flow-stress response is based on *L. natalensis* which is known reasonably well

Are there suitable interpretive indices available? (SASS, H-FSR)
Limited species richness (1-3 species) is too low to make application of current version of FAII useful.

Can you discern between flow and non-flow related problems?
Flow and non-flow related problems can be distinguished.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate

6.3.5 Aquatic invertebrates

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Species level historical information (1960) is available. For recent survey two site visits to a single site are insufficient especially as these were within the same season. There is also no other data from the same ecoregion type.

Is recent information available?
Year 2001

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding at a crude level – species level information and knowledge of species biology would be necessary to better understand.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Understanding at a crude level – species level information and knowledge of species biology would be necessary to better understand habitat-flow-stress responses. Understanding of non-flow related issues (e.g. water quality) is better.

Are there suitable interpretive indices available? (SASS, H-FSR)
SASS is useful but does not adequately deal with flow-related issues.

Can you discern between flow and non-flow related problems?
Only to a limited extent.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?

Moderate
Due to the already impacted nature of the invertebrate fauna, the scope to interpret changes is reduced.

6.4 MONITORING REQUIREMENTS

The monitoring requirements are listed in the following tables.

Table 6.2 Monitoring requirements for geomorphology – IFR 1

The baseline monitoring requirements below are applicable to IFR 1 - 7,11,14,16. Long-term monitoring requirements are applicable to all IFR sites.

BASELINE[1]									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Helicopter survey and digital video	1	Dry	Once off	3[2]					
Analyse aerial photographs and available remote sensing data	1	Dry	Once off			0.5	0.5	0.5	0.5
Analyse available hydrological data	1		Once off					1	
Geomorphological mapping	1	Dry	Once off			1		0.5	
Ground truthing	1	Dry	Once off	1					
LONG-TERM MONITORING (5yr)									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
Update	1	Dry	1	3[2]					
Update where available	1	Dry	1			0.5	0.5	0.5	0.5
Update	1		1			1		1	
Update	1	Dry	1			1		0.5	
Update	1	Dry	1	1					

1 To develop a conceptual understanding and description of the natural functioning and characteristics of the Thukela River system (physical template; driver; material)
2 Total time for helicopter survey

Table 6.3 Monitoring requirements for riparian vegetation – IFR 1

The baseline monitoring requirements below are applicable to IFR 1 - 7,11,14,16. Long-term monitoring requirements are applicable to all IFR sites.

BASELINE									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Helicopter survey and digital video	1	Dry	Once off	4		0.2		0.1	
Analyse aerial photographs and available remote sensing data	1	Dry	Once off			1	1	0.1	
Analyse available hydrological data	1		Once off	0					
Vegetation mapping	1	Dry	Once off			1		0.2	
Ground truthing	1	Dry	Once off	0.7		0.4		0.1	

LONG-TERM (5YR)									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Update	1	Dry	1	4		0.2		0.1	
Update where available	1	Dry	1			1	1	0.1	
Update	1		1	0					
Update	1	Dry	1			1		0.2	
Update	1	Dry	1	0.5		0.4		0.1	

Table 6.4 Monitoring requirements for water quality – IFR 1

<table>
<tr><th colspan="10">BASELINE</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Continue monthly monitoring at V1H026.</td><td>Inorganic salts</td><td></td><td>Monthly</td><td rowspan="4"></td><td rowspan="4">6 (samples collected simultaneously)</td><td rowspan="4"></td><td rowspan="4">6</td><td rowspan="4">1</td><td rowspan="4">1</td></tr>
<tr><td>Increase frequency to twice a month if there are major developments in the catchment.</td><td>Nutrients (SRP, TIN)</td><td></td><td>Monthly</td></tr>
<tr><td>Add turbidity to routine sampling, and record temperature (as below Driel barrage) and DO during sample collection.</td><td>System variables (pH, temp, turbidity, DO)</td><td></td><td>Monthly</td></tr>
<tr><td>Collect periphyton samples for chl-a analysis as no baseline exists.</td><td>Algal abundance (chl-a)</td><td></td><td>Monthly</td></tr>
<tr><th colspan="10">LONG-TERM (5YR)</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Continue monthly monitoring at V1H026.</td><td>Inorganic salts</td><td rowspan="4"></td><td>Monthly</td><td rowspan="4"></td><td rowspan="4">30 (samples collected simultaneously)</td><td rowspan="3"></td><td rowspan="3">30</td><td rowspan="5">4</td><td rowspan="5"></td></tr>
<tr><td>Increase frequency to twice a month if there are major developments in the catchment.</td><td>Nutrients (SRP, TIN)</td><td>Monthly</td></tr>
<tr><td>Add turbidity to routine sampling, and record temperature (as below Driel barrage) and DO during sample collection.</td><td>System variables (pH, temp, turbidity, DO)</td><td>Monthly</td></tr>
<tr><td>In-stream toxicity tests when poor biotic surveys not due to flow or habitat conditions.</td><td>In-stream toxicity</td><td>React to biotic index</td><td></td><td>4 days per series of tests</td></tr>
<tr><td>Collect periphyton samples for quarterly analysis (i.e. per season).</td><td>Algal abundance (chl-a)</td><td>S, W, A, Sp</td><td>4 (i.e. per season) / year</td><td></td><td>10</td><td></td><td>10</td></tr>
</table>

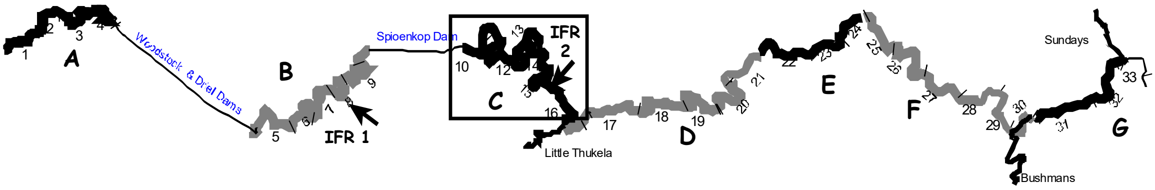
Table 6.5 Monitoring requirements for fish – IFR 1

BASELINE									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
Fish survey at IFR site (and section of river reach).	1,2,3	Low flow season	1 Low flow season	1	1	0.5		0.5	
Seine sampling (10 efforts distributed over the section) and electro fishing (>40 minutes effort, 2 passes). Sampling quantified (CPUE, etc.)									
Determine length frequencies, age classes.									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).									
LONG-TERM (5YR)									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
Fish survey at IFR site (and section of river reach).	1, 2, 3	Low flow season	1 low flow season for 3 years during the baseline phase		2	0.5		0.5	
Seine sampling (and electro fishing (>40 minutes effort and/or 2 passes). Sampling quantified (CPUE, etc.).									
Determine length frequencies, age classes.									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming)									

Table 6.6 Monitoring requirements for aquatic invertebrates – IFR 1

BASELINE									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
SASS5 survey at IFR1 site.	1-6	Autumn	1		0.3	0.25		0.3	
		Winter	1		0.3				
		Spring	1		0.3				
Carry out habitat assessment at IFR 1 site	7	Autumn	1		0.1				
		Winter	1		0.1				
		Spring	1		0.1				
LONG-TERM (5YR)									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
SASS5 survey at IFR1 site.	1-6					0		1.5	
Carry out habitat assessment at IFR 1 site	7	Winter	5		1.5				

7 RU C. IFR 2. SKIETDRIFT (Upper Thukela River)



7.1 SITE SELECTION

The site is situated approximately 20km downstream of Spioenkop Dam. The channel is a mixed bed with both bedrock and a combination of fine and coarse material. It is incised within a historic floodplain. A bedrock dyke occurs across the river and mid channel bars with *Phragmites*. Vegetation on the banks is a mixture of indigenous and exotic vegetation. This section of river is subject to unseasonal releases from Spioenkop Dam.

7.2 ECOSPECS AND TPCs

Table 7.1 The various Ecospecs and related TPCs for each component – IFR 2

ECOSPECS	TPCs
Geomorphology	
1. To maintain the trajectory and relative location, composition and structure of morphological units within a reach (within a resource unit).	1. A significant change in the trajectory and relative location, composition and structure of morphological units within a reach (within a geomorphological zone).
Riparian vegetation	
1. To maintain the trajectory and relative location, extent, composition and structure of riparian and marginal vegetation on morphological units within a reach (within a resource unit).	1. A significant change in the trajectory of riparian and marginal vegetation on morphological units within a reach (within a resource unit).
Water quality	
1. Inorganic salts (magnesium sulphate, magnesium chloride, sodium sulphate, sodium chloride, calcium sulphate, calcium chloride) or salt ions.	1. 95%ile of data must not exceed the category A upper boundary as defined by the quality ecospecs.
2. Nutrients: SRP (synonymous with PO4 or orthophosphate).	2. 50%ile of data must not exceed the category C upper boundary as defined by the quality ecospecs.
3. Nutrients: TIN.	3. 50%ile of data must not exceed the category A/B upper boundary as defined by the quality ecospecs.
4. System variables: pH, DO, temperature.	4. 95%ile of data must not exceed the category B (good) upper boundary as defined by the quality ecospecs.
5. System variables: turbidity / SS.	5. A TPC cannot be provided, as no data or method is currently available. Noted as developmental issue.
6. Algal abundance (chl-a).	6. Concentration must not exceed the quality ecospec for periphyton.
7. In-stream toxicity (minimum is *Daphnia*, fish and algal tests).	7. Any indication of toxicity as shown by any single test as specified in the ecospecs column (i.e. *Daphnia*, fish or algal test).
Fish	
1. All 3 species expected for a C category should be present: *Labeobarbus natalensis, Labeo rubromaculatus, Amphilius natalensis*. (I.e. viable populations). Fish health and condition should be moderate to good.	1. Absence of any of the species.
2. All year classes of all species represented.	2. Absence or drop in abundance of any year class.
3. Maintain critical stress level below 6.0 to facilitate year round riffle habitat for *A. natalensis:* FD=2 FS=2 SD=3 SS=3 HABITAT SUITABILITY RATING: • Breeding = 1 • Survival/Abundance = 2 • Cover = 2 • Health = 3	3. Drop in abundance of any of the flow-depth and cover classes (which would relate to increased stress).

ECOSPECS	TPCs
• Water quality = 3	
Aquatic invertebrates	
1. To ensure that the SASS5 scores and ASPT values occur in the set range (except after major floods and during droughts). Stones biotope: SASS >120, ASPT >6.5 Vegetation biotope: SASS >60, ASPT >6.5	1. Stones biotope: SASS5 score <130 and ASPT <6.5 in winter. Vegetation biotope: SASS5 score <60 and ASPT <6.5 in winter
2. Ensure that no invertebrate taxon consistently dominates the fauna.	2. When any taxon has an abundance of >100 while all other taxa are <10, for two consecutive surveys.
3. Flow regime to maintain the current speeds for rheophilic species.	3. Abundance of rheophilic taxa in total <100 individuals 3 families of Ephemeroptera.
4. Maintain suitable conditions for filter feeding organisms such as Hydropsychidae and Simuliidae.	4. Hydropsychidae or Simuliidae absent for two consecutive surveys.

7.3 ANALYSIS OF LIMITATIONS IN AVAILABLE INFORMATION

7.3.1 Water quality

Conditions to be maintained, therefore water quality to be a B category. RU C consists of a single QRU. No water quality issues are anticipated.

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Yes

Is recent information available?
No

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Yes

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Not required as water quality and macroinvertebrate conditions good. Increases in nutrients and subsequent periphyton production will result in the formation of biofilms and affect biotic scores.

Are there suitable interpretive indices available? (SASS, H-FSR)
No. Include turbidity, DO and temperature (as downstream of Spioenkop Dam).

Can you discern between flow and non-flow related problems?
Yes

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate - High

7.3.2 Fish

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Information not very suitable. Proper baseline required.

Is recent information available?
No Recent information.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding of the requirements of the target species present is generally sufficient. Interpretive knowledge on the habitat-flow-stress response is based on *A. natalensis* which is well known.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Five species expected to be present but proper baseline required to construct a FAII.

Are there suitable interpretive indices available? (SASS, H-FSR)
The flow stress habitat response provides a suitable interpretive index.

Can you discern between flow and non-flow related problems?
Flow and non-flow related problems can be distinguished.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate

7.3.3 Aquatic invertebrates

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
One historical survey from the same zone and only one survey for this present study is available. No information from neighbouring ecoregion types is available.

Is recent information available?
One survey in 2001.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding is at a crude level – species level information and knowledge of species biology would be necessary for a better understanding.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Understanding is at a crude level – species level information and knowledge of species biology would be necessary to better understand habitat-flow-stress responses. Understanding of non-flow related issues (e.g. water quality) is better.

Are there suitable interpretive indices available? (SASS, H-FSR)
SASS is useful but does not adequately deal with flow-related issues.

Can you discern between flow and non-flow related problems?
Only to a limited extent.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate
There is no information about the natural variability at this site.

7.4 Monitoring requirements

The monitoring requirements are listed in the following tables.

Table 7.2 Monitoring requirements for water quality – IFR 2

<table>
<tr><th colspan="10">BASELINE</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Continue monthly monitoring at V1H057.</td><td>Inorganic salts.</td><td></td><td>Monthly</td><td rowspan="4"></td><td rowspan="4">6 (samples collected simultaneously)</td><td rowspan="4"></td><td rowspan="4">6</td><td rowspan="4">1</td><td rowspan="4"></td></tr>
<tr><td>Increase frequency to twice a month if there are major developments in the catchment.</td><td>Nutrients (SRP, TIN).</td><td></td><td>Monthly</td></tr>
<tr><td>Add turbidity to routine sampling, and record temperature (as below Spioenkop Dam) and DO during sample collection.</td><td>System variables (pH, temp. turbidity, DO).</td><td></td><td>Monthly</td></tr>
<tr><td>Collect periphyton samples for chl-a analysis as no baseline exists.</td><td>Algal abundance (chl-a).</td><td></td><td>Monthly</td></tr>
<tr><th colspan="10">LONG-TERM (5YR)</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="3">Survey</th><th colspan="2">Analysis</th><th>Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Continue monthly monitoring at V1H057.</td><td>Inorganic salts</td><td></td><td>Monthly</td><td rowspan="5"></td><td rowspan="4">30 (samples collected simultaneously)</td><td rowspan="5"></td><td rowspan="3">30</td><td rowspan="5">4</td><td rowspan="5"></td></tr>
<tr><td>Increase frequency to twice a month if there are major developments in the catchment.</td><td>Nutrients (SRP, TIN)</td><td></td><td>Monthly</td></tr>
<tr><td>Add turbidity to routine sampling, and record temperature (as below Spioenkop Dam) and DO during sample collection.</td><td>System variables (pH, temp. turbidity, DO)</td><td></td><td>Monthly</td></tr>
<tr><td>In-stream toxicity tests when poor biotic surveys not due to flow or habitat conditions.</td><td>Instream toxicity</td><td></td><td>React to biotic index</td><td>4 days per series of tests.</td></tr>
<tr><td>Collect periphyton samples for analysis when indicated by biotic response.</td><td>Algal abundance (chl-a)</td><td></td><td>React to biotic index</td><td></td><td>0.5 days per analysis</td></tr>
</table>

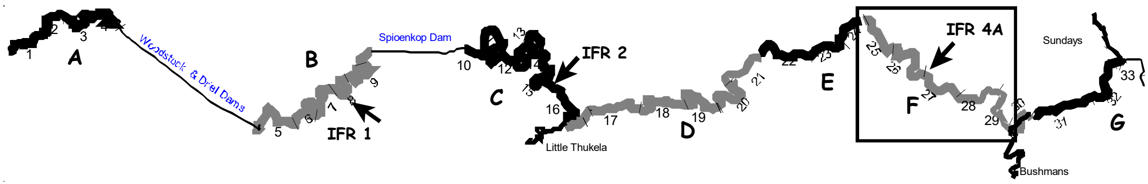
Table 7.3 Monitoring requirements for fish – IFR 2

BASELINE									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Fish survey at IFR site (and section of river reach). Seine sampling (10 efforts distributed over the section) and electro fishing (>40 minutes effort, 2 passes). Sampling quantified (CPUE, etc.). Determine length frequencies, age classes. Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data. Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming)	1, 2, 3	Low flow season	1 low flow season	1	1	0.5		0.5	
LONG-TERM (5YR)									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
Fish survey at IFR site (and section of river reach). Seine sampling (and electro fishing (>40 minutes effort and/or 2 passes). Sampling quantified (CPUE, etc.) Determine length frequencies, age classes. Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data. Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming)	1, 2, 3	Low flow season	1 low flow season for 3 years during the baseline phase		2	0.5		0.5	

Table 7.4 Monitoring requirements for aquatic invertebrates – IFR 2

BASELINE									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
SASS5 survey at IFR2 site.	1-4	Autumn	1		0.3	0.25		0.3	
		Winter	1		0.3				
		Spring	1		0.3				
Carry out habitat assessment at IFR 2 site.	3-4	Autumn	1		0.1				
		Winter	1		0.1				
		Spring	1		0.1				
LONG-TERM (5YR)									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
SASS5 survey at IFR1 site.	1-4	Winter	5		1.5	0.5		1.5	
Carry out habitat assessment at IFR 1 site.	3-4	Winter	5		1.5				

8 RU F. IFR 4a. ZINGELA (Upper Thukela River)



8.1 SITE DESCRIPTION

The site is situated downstream of the Klip confluence and the proposed Jana Dam wall. This site is an existing site that was used as a site for habitat modelling and sediment transport modelling during 2000. The channel consists of mixed pool/rapid morphology and bed material consists of bedrock, boulders and cobble. Indigenous vegetation occurs on the banks with *Phragmites*, and sedges on the river edges.

8.2 ECOSPECS AND TPCs

Table 8.1 The various Ecospecs and related TPCs for each component – IFR 4

ECOSPECS	TPCs
Geomorphology	
1. To maintain the trajectory and relative location, composition and structure of morphological units within a reach (within a resource unit).	1. A significant change in the trajectory and relative location, composition and structure of morphological units within a reach (within a geomorphological zone).
Riparian vegetation	
1. To maintain the trajectory and relative location, extent, composition and structure of riparian and marginal vegetation on morphological units within a reach (within a resource unit).	1. A significant change in the trajectory of riparian and marginal vegetation on morphological units within a reach (within a resource unit).
Water quality (Due to lack of data, TPCs are single values that must not be exceeded)	
1. Inorganic salts or salt ions: magnesium sulphate.	1. 28 mg/L (upper boundary for a C category).
2. Inorganic salts or salt ions: sodium sulphate.	2. 38 mg/L (upper boundary for a C category).
3. Inorganic salts or salt ions: magnesium chloride.	3. 15 mg/L (upper boundary for an A category).
4. Inorganic salts or salt ions: calcium chloride.	4. 57 mg/L (upper boundary for a B category).
5. Inorganic salts or salt ions: sodium chloride.	5. 45 mg/L (upper boundary for an A category).
6. Inorganic salts or salt ions: calcium sulphate.	6. 351 mg/L (upper boundary for an A category).
7. Nutrients: SRP (synonymous with PO4 or orthophosphate).	7. 0.091 mg/L (upper boundary for a C/D category).
8. Nutrients: TIN.	8. 3.0 mg/L (upper boundary for a C/D category).
9. System variables: pH.	9. Data must be within the range 6.5 - 8.0.
10. System variables: DO.	10. Data must not drop below 6 mg/L.
11. System variables: turbidity / SS.	11. A TPC cannot be provided as no data or method is currently available. Noted as developmental issue.
12. Algal abundance (chl-a): phytoplankton.	12. Concentration should be below 20 ug/L (i.e. upper boundary for the B category).
13. Algal abundance (chl-a): periphyton.	13. Concentration should be below 260 mg/m^2 (i.e. upper boundary for the C category).
14. In-stream toxicity (minimum is *Daphnia*, fish and algal tests).	14. Any indication of toxicity as shown by any single test as specified in the ecospecs column (i.e. *Daphnia*, fish or algal test).
Fish	
1. All 12 species expected for a C/D category should be present but a considerable drop in abundance from a B category: *Labeobarbus natalensis, Labeo rubromaculatus, Amphilius natalensis, Anguilla mossambica, Barbus anoplus etc*. (i.e. viable populations). Fish health and condition should be moderate to good.	1.Absence of any of the species.

ECOSPECS	TPCs
2. All year classes of all species represented.	2. Absence or drop in abundance of any year class.
3. Maintain critical stress level below 7.5 to facilitate year round riffle habitat for *A. natalensis:* FD = 1 FS = 1 SD = 4 SS = 4 HABITAT SUITABILITY RATING: • Breeding = 1 • Survival/Abundance = 3 • Cover = 3 • Health = 3 • Water quality = 3	3. Drop in abundance of any of the flow-depth and cover classes (which would relate to increased stress).
Aquatic invertebrates	
1. To ensure that the SASS5 scores and ASPT values occur in the set range (except after major floods and during droughts). Stones biotope: SASS >110 ASPT >6.5 (in winter). Vegetation biotope: SASS >90, ASPT >6 (in winter).	1. Stones biotope: SASS5 score <100 and ASPT <6.5 in winter. Vegetation biotope: SASS5 score <80 and ASPT <6 in winter.
2. Ensure that no invertebrate taxon consistently dominates the fauna.	2. When any taxon has an abundance of >100 while all other taxa are <10, for two consecutive surveys.
3. Flow regime to maintain the current speeds for rheophilic species.	3. Abundance of rheophilic taxa in total <100 individuals 3 families of Ephemeroptera.
4. Maintain suitable conditions for filter feeding organisms Hydropsychidae and Simuliidae.	4. Either Hydropsychidae or Simuliidae absent for two consecutive surveys.
5. Flow regime to maintain the current diversity of biotopes.	5. Either SIC, SOOC or Marginal Vegetation biotopes are lost to invertebrates.
6. *Macrobrachium sp.* to occur at this site.	6. No individuals collected two surveys consecutively.

8.3 ANALYSIS OF LIMITATIONS IN AVAILABLE INFORMATION

8.3.1 Water quality

Water quality will be maintained at a C category. However, data confidence is low as limited monitoring was conducted (8 data sets collected during the low flow season of 2001) during the project, and DWAF has to institute monitoring at this site. (Note that as limited water quality data is currently available, and medians and 95%iles cannot be produced, TPCs have been set as single values that must not be exceeded.) Due to the low confidence in the assessment, it is recommended that nutrients be maintained at least at a C/D category. This may require some control over the Klip River input. RU F contains two QRUs, which are combined due to data limitations.

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
No

Is recent information available?
Yes

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
No

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
No, as no water quality data is available.

Are there suitable interpretive indices available? (SASS, H-FSR)
No monitoring currently being undertaken.

Can you discern between flow and non-flow related problems?
No

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Low

8.3.2 Fish

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Information not very suitable. Proper baseline required.

Is recent information available?
No Recent information is available.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding of the requirements of the target species present is generally sufficient. Interpretive knowledge on the habitat-flow-stress response is based on *A. natalensis* which is well known.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Twelve species expected to be present but proper baseline required to construct a FAII.

Are there suitable interpretive indices available? (SASS, H-FSR)
The flow stress habitat response provides a suitable interpretive index.

Can you discern between flow and non-flow related problems?
Flow and non-flow related problems can be distinguished.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate

8.3.3 Aquatic invertebrates

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Good historical information (1960) from sites nearby is available.

Is recent information available?
Yes, De Moor (1999) and this study (2001)

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Moderate understanding – species level information is available but biology is still unclear.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues).
Moderate understanding – species level information is available but better understanding of biology is required to better understand habitat-flow-stress responses. Understanding of non-flow related issues (e.g. water quality) is better.

Are there suitable interpretive indices available? (SASS, H-FSR)
SASS is useful but does not adequately deal with flow-related issues.

Can you discern between flow and non-flow related problems?
Only to a limited extent.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
High/Moderate
Although there is good historical data there is insufficient SASS data to check natural variability. There are also concerns about the large changes in important flow related groups (especially Hydropsychidae) that have taken place between 1960 and the present which have not been explained.

8.4 MONITORING REQUIREMENTS

The monitoring requirements are listed in the following tables.

Table 8.2 Monitoring requirements for water quality – IFR 4

<table>
<tr><th colspan="10">BASELINE</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/
TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td rowspan="2">Institute bimonthly monitoring just above the IFR site (and below the input of the Klip River.</td><td>Inorganic salts</td><td></td><td>Bimonthly</td><td rowspan="4"></td><td rowspan="4">10 (samples collected simultaneously)</td><td rowspan="4"></td><td rowspan="4">10</td><td rowspan="4">1</td><td rowspan="4"></td></tr>
<tr><td>Nutrients (SRP, TIN)</td><td></td><td>Bimonthly</td></tr>
<tr><td>Add turbidity to routine sampling, and record DO during sample collection.</td><td>System variables (pH, turbidity and DO)</td><td></td><td>Bimonthly</td></tr>
<tr><td>Collect periphyton samples for chl-a analysis as no baseline exists.</td><td>Algal abundance (chl-a)</td><td></td><td>Monthly</td></tr>
<tr><th colspan="10">LONG-TERM (5YR)</th></tr>
<tr><th rowspan="3">ACTION</th><th rowspan="3">Ecospec/
TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Continue bimonthly monitoring at selected site (as a new site and little data exists).</td><td>Inorganic salts, Nutrients (SRP, TIN)</td><td></td><td>Bimonthly</td><td rowspan="4"></td><td rowspan="3">50 (samples collected simultaneously)</td><td rowspan="4"></td><td rowspan="2">50</td><td rowspan="4">4</td><td rowspan="4"></td></tr>
<tr><td>Add turbidity to routine sampling, and record DO during sample collection.</td><td>System variables (pH, turbidity and DO)</td><td></td><td>Bimonthly</td></tr>
<tr><td>Collect periphyton samples for quarterly analysis (i.e. per season).</td><td>Algal abundance (chl-a)</td><td>S, W, A, Sp</td><td>4 (i.e. per season) / year</td><td></td></tr>
<tr><td>In-stream toxicity tests when poor biotic surveys not due to flow or habitat conditions.</td><td>In-stream toxicity</td><td></td><td>React to biotic index</td><td></td><td>4 days per series of tests.</td></tr>
</table>

Table 8.3 Monitoring requirements for fish – IFR 4

BASELINE

Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Fish survey at IFR site (and section of river reach).	1, 2, 3	Low flow season	1 low flow season	1	1	0.5		0.5	
Seine sampling (10 efforts distributed over the section) and electro fishing (>40 minutes effort, 2 passes). Sampling quantified (CPUE, etc.).									
Determine length frequencies, age classes.									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).									

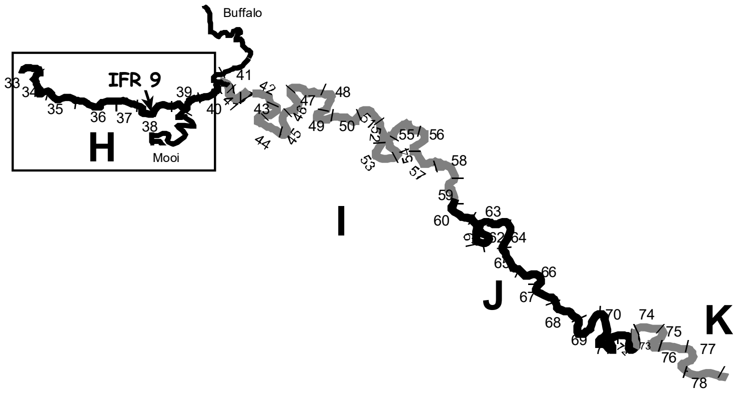
LONG-TERM (5YR)

Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Fish survey at IFR site (and section of river reach).	1, 2, 3	Low flow season	1 low flow season for 3 years during the baseline phase		2	0.5		0.5	
Seine sampling (and electro fishing (>40 minutes effort and/or 2 passes). Sampling quantified (CPUE, etc.).									
Determine length frequencies, age classes.									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).									

Table 8.4 Monitoring requirements for aquatic invertebrates – IFR 4

BASELINE									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
SASS5 survey at IFR4 site.	1-4	Autumn	1		0.3	0.25		0.3	
		Winter	1		0.3				
		Spring	1		0.3				
Carry out habitat assessment at IFR 4 site.	5	Autumn	1		0.1				
		Winter	1		0.1				
		Spring	1		0.1				
Survey for *Macrobrachium* as part of fish survey.	6	Winter	1		Linked to fish sample	Analysis linked to estuarine specialist		Analysis linked to estuarine specialist	
LONG-TERM (5YR)									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
SASS5 survey at IFR 4 site.	1-4	Winter				0.5		1.5	
			5		1.5				
Carry out habitat assessment at IFR 4 site.	5	Winter	5		1.5				
Survey for *Macrobrachium* as part of fish survey.	6	Winter	5		Linked to fish sample	Analysis linked to estuarine specialist		Analysis linked to estuarine specialist	

9 RU H. IFR 9. THUKELA FERRY (Upper Thukela River)



9.1 SITE DESCRIPTION

The site is situated downstream of Tugela Ferry and approximately 5km upstream of the Mooi River confluence. The site is characterised by a steep boulder rapid with a steep hillside on the right bank and a wide cobble bar on the left bank.

9.2 ECOSPECS AND TPCs

Table 9.1 The various Ecospecs and related TPCs for each component – IFR 9

ECOSPECS	TPCs
Geomorphology	
1. To maintain the trajectory and relative location, composition and structure of morphological units within a reach (within a resource unit).	1. A significant change in the trajectory and relative location, composition and structure of morphological units within a reach (within a geomorphological zone).
Riparian vegetation	
1. To maintain the trajectory and relative location, extent, composition and structure of riparian and marginal vegetation on morphological units within a reach (within a resource unit).	1. A significant change in the trajectory of riparian and marginal vegetation on morphological units within a reach (within a resource unit).
Fish	
1. All 12 species expected for a C category should be present: *Labeobarbus natalensis*, *Labeo rubromaculatus*, *Amphilius natalensis*, *Anguilla bengalensis*, *A. marmorata*, A. *mossambicus*, Barbus *anoplus* etc. (I.e. viable populations). Fish health and condition should be moderate to good.	1.Absence of any of the species.
2. All year classes of all species represented	2. Absence or drop in abundance of any year class
3. Maintain critical stress level below 7.5 to facilitate year round riffle habitat for *A. natalensis* and habitat and passage for *L. natalensis* and Anguillids, (3 eel species in this reach): FD = 2 FS = 3 SD = 4 SS = 3. HABITAT SUITABILITY RATING: • Breeding = 2 • Survival/Abundance = 3 • Cover = 2 • Health = 4 • Water quality = 4	3. Drop in abundance of any of the flow-depth and cover classes (which would relate to increased stress)
Aquatic invertebrates	
1. To ensure that the SASS5 scores and ASPT values occur in the set range (except after major floods and during droughts). Stones biotope: SASS >110 ASPT >5.5 (in winter).	1. Stones biotope SASS5 score <90 and ASPT <5 in winter.
2. Ensure that no invertebrate taxon consistently dominates the fauna.	2. When any taxon has an abundance of >100 while all other taxa are <10, for two consecutive surveys.
3. Maintain presence of diverse mayfly taxa in stones biotope.	3. At most, less than 2 families of mayflies may be lost/missed between any two consecutive surveys.
4. Maintain suitable conditions for filter feeding organisms such as Hydropsychidae and Simuliidae.	4. Hydropsychidae or Simuliidae absent for two consecutive surveys.
5. Flow regime to maintain the current speeds for rheophilic species.	5. Abundance of rheophilic taxa in total <100 individuals.

9.3 ANALYSIS OF LIMITATIONS IN AVAILABLE INFORMATION

9.3.1 Fish

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Information not very suitable. Proper baseline required.

Is recent information available?
No recent information is available.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding of the requirements of the target species present is generally sufficient.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Interpretive knowledge on the habitat-flow-stress response is based on *A. natalensis, L. natalensis* and Anguillids which are well known.
Twelve species expected to be present but proper baseline required to construct a FAII.

Are there suitable interpretive indices available? (SASS, H-FSR)
The flow stress habitat response provides a suitable interpretive index.

Can you discern between flow and non-flow related problems?
Flow and non-flow related problems can be distinguished.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate

9.3.2 Aquatic invertebrates

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Very poor information, no surveys undertaken.

Is recent information available?
No, reference was made to Chutter's 1995 report (no raw data).

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding is negligible due to shortage of data.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Understanding is negligible due to shortage of data.

Are there suitable interpretive indices available? (SASS, H-FSR)
SASS is useful but does not adequately deal with flow-related issues.

Can you discern between flow and non-flow related problems?
Not without data (as it currently stands).

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Low.
Due to absence of data.

9.4 MONITORING REQUIREMENTS

The monitoring requirements are listed in the following tables.

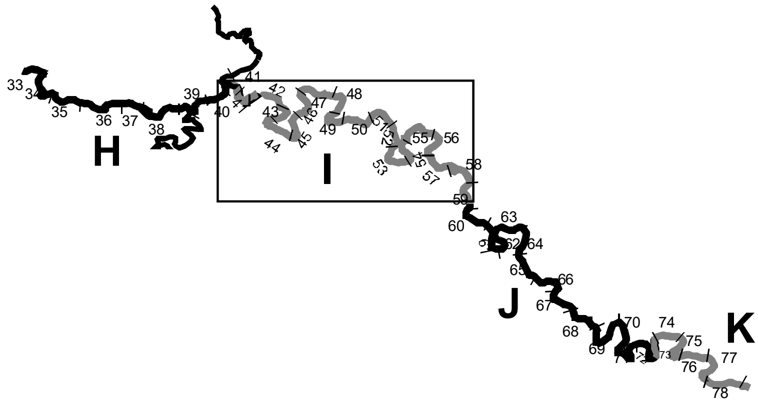
Table 9.2 Monitoring requirements for fish – IFR 9

BASELINE									
ACTION	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Fish survey at IFR site (and section of river reach).	1, 2, 3	Low flow season	1 Low flow season	1	1	0.5		0.5	
Seine sampling (10 efforts distributed over the section) and electro fishing (>40 minutes effort, 2 passes).									
Sampling quantified (CPUE, etc.).									
Determine length frequencies, age classes.									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).									

Table 9.3 Monitoring requirements for aquatic invertebrates – IFR 9

BASELINE									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
SASS5 survey at IFR 9 site.	1-5	Autumn	1		0.3	0.25		0.3	
		Winter	1		0.3				
		Spring	1		0.3				
Carry out habitat assessment at IFR 9 site.	4+5	Autumn	1		0.1				
		Winter	1		0.1				
		Spring	1		0.1				

10 RU I. IFR 15. JAMESON'S DRIFT (Lower Thukela)



10.1 SITE DESCRIPTION

The site is situated downstream of Jameson's Drift. Alluvial channel with pool/riffle morphology and a bed consisting of a mixed cobble with gravel and sand matrix.

10.2 ECOSPECS AND TPCs

Table 10.1 The various Ecospecs and related TPCs for each component – IFR 15

ECOSPECS	TPCs
Geomorphology	
1. To maintain the trajectory and relative location, composition and structure of morphological units within a reach (within a resource unit).	1. A significant change in the trajectory and relative location, composition and structure of morphological units within a reach (within a geomorphological zone).
Riparian vegetation	
1. To maintain the trajectory and relative location, extent, composition and structure of riparian and marginal vegetation on morphological units within a reach (within a resource unit)	1. A significant change in the trajectory of riparian and marginal vegetation on morphological units within a reach (within a resource unit).
Fish	
1. All 12 species expected for a C category should be present: *Labeobarbus natalensis, Labeo rubromaculatus, Amphilius natalensis, Anguilla bengalensis, Anguilla marmorata, Barbus anoplus etc*. (I.e. viable populations). Fish health and condition should be moderate to good.	1. Absence of any of the species.
2. All year classes of all species represented	2. Absence or drop in abundance of any year class.
3. Maintain critical stress level below 6 to facilitate year round riffle habitat for *A. natalensis* (but extinct from site) and habitat and passage for Anguillids: FD =3 FS = 4 SD = 4 SS = 4. HABITAT SUITABILITY RATING: • Breeding = 4 • Survival/Abundance = 4 • Cover = 4 • Health = 5 • Water quality =5	3. Drop in abundance of any of the flow-depth and cover classes (which would relate to increased stress).
Aquatic invertebrates	
1. To ensure that the SASS5 scores and ASPT values occur in the set range (except after major floods and during droughts). Stones biotope: SASS >130 ASPT >6 (in winter).	1. Stones biotope SASS5 score <120 and ASPT <6 in winter.
2. Ensure that no invertebrate taxon consistently dominates the fauna.	2. When any taxon has an abundance of >100 while all other taxa are <10, for two consecutive surveys.
3. Maintain suitable conditions for filter feeding organisms such as Hydropsychidae and Simuliidae.	3. Hydropsychidae absent or Simuliidae occur at abundance <10 for two consecutive surveys.
4. Flow regime to maintain the current speeds for rheophilic taxa such as Heptageniidae, Simuliidae, Oligoneuridae, Elmidae and Perlidae	4. Abundance of rheophilic taxa in total <100 individuals
5. Maintain presence of Macrobrachium diversity (if present).	5. Absence of 2 species (if >2 species are found) other than *M. ruda* for 2 consecutive years.

10.3 ANALYSIS OF LIMITATIONS IN AVAILABLE INFORMATION

10.3.1 Fish

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Information not very suitable. Proper baseline required.

Is recent information available?
No recent information is available.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding of the requirements of the target species present is generally sufficient.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Interpretive knowledge on the habitat-flow-stress response is based on *A. natalensis* which is well known.
Twelve species expected to be present but proper baseline required to construct a FAII.

Are there suitable interpretive indices available? (SASS, H-FSR)
The flow stress habitat response provides a suitable interpretive index.

Can you discern between flow and non-flow related problems?
Flow and non-flow related problems can be distinguished.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate

10.3.2 Aquatic invertebrates

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Historical information occurs only for the Middledrift area.

Is recent information available?
Two surveys from 2001 from two sites in the same Resource Unit.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding is at a crude level – species level information and knowledge of species biology would be necessary for a better understanding.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Understanding is at a crude level – species level information and knowledge of species biology would be necessary to better understand habitat-flow-stress responses. Understanding of non-flow related issues (e.g. water quality) is better.

Are there suitable interpretive indices available? (SASS, H-FSR)
SASS is useful but does not adequately deal with flow-related issues.

Can you discern between flow and non-flow related problems?
Only to a limited extent. .

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate
Several flow and water quality sensitive taxa are present at this site which allows confidence in the interpretation.

10.4 MONITORING REQUIREMENTS

The monitoring requirements are listed in the following tables.

Table 10.2 Monitoring requirements for aquatic invertebrates – IFR 15

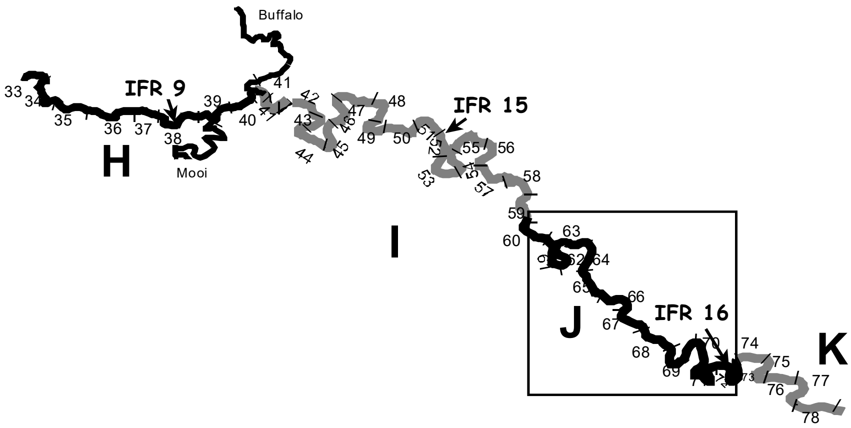
BASELINE									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
SASS5 survey at IFR 15 site.	1-4	Autumn	1		0.3	0.25		0.3	
		Winter	1		0.3				
		Spring	1		0.3				
Carry out habitat assessment at IFR 15 site.	4	Autumn	1		0.1				
		Winter	1		0.1				
		Spring	1		0.1				
Survey for *Macrobrachium* as part of fish survey.	5	Winter	1		Linked to fish sample	Analysis linked to estuarine specialist		Analysis linked to estuarine specialist	

LONG-TERM (5YR)									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
SASS5 survey at IFR 15 site.	1-4					0.5		1.5	
		Winter	5		1.5				
Carry out habitat assessment at IFR 15 site.	4	Winter	5		1.5				
Survey for *Macrobrachium* as part of fish survey.	5	Winter	5		Linked to fish sample	Analysis linked to estuarine specialist		Analysis linked to estuarine specialist	

Table 10.3 Monitoring requirements for fish – IFR 15

<table>
<tr><th colspan="10">BASELINE</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Fish survey at IFR site (and section of river reach).</td><td rowspan="5">1, 2, 3</td><td rowspan="5">Low flow season</td><td rowspan="5">1 low flow season</td><td rowspan="5">1</td><td rowspan="5">1</td><td rowspan="5">0.5</td><td rowspan="5"></td><td rowspan="5">0.5</td><td rowspan="5"></td></tr>
<tr><td>Seine sampling (10 efforts distributed over the section) and electro fishing (>40 minutes effort, 2 passes). Sampling quantified (CPUE, etc.).</td></tr>
<tr><td>Determine length frequencies, age classes.</td></tr>
<tr><td>Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.</td></tr>
<tr><td>Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).</td></tr>
<tr><th colspan="10">LONG-TERM (5YR)</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Fish survey at IFR site (and section of river reach).</td><td rowspan="5">1, 2, 3</td><td rowspan="5">Low flow season</td><td rowspan="5">1 low flow season for 3 years during the baseline phase</td><td rowspan="5"></td><td rowspan="5">2</td><td rowspan="5">0.5</td><td rowspan="5"></td><td rowspan="5">0.5</td><td rowspan="5"></td></tr>
<tr><td>Seine sampling (and electro fishing (>40 minutes effort and/or 2 passes). Sampling quantified (CPUE, etc.).</td></tr>
<tr><td>Determine length frequencies, age classes.</td></tr>
<tr><td>Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.</td></tr>
<tr><td>Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).</td></tr>
</table>

11 RU J. IFR 16. MANDINI (Lower Thukela River)



11.1 SITE DESCRIPTION

The site is situated about 7km upstream of the Mandini gauge. The site consists of an alluvial section with large boulder bar on the left bank.

11.2 ECOSPECS AND TPCs

Table 11.1 The various Ecospecs and related TPCs for each component – IFR 16

ECOSPECS	TPCs
Geomorphology	
1. To maintain the trajectory and relative location, composition and structure of morphological units within a reach (within a resource unit).	1. A significant change in the trajectory and relative location, composition and structure of morphological units within a reach (within a geomorphological zone).
Riparian vegetation	
1. To maintain the trajectory and relative location, extent, composition and structure of riparian and marginal vegetation on morphological units within a reach (within a resource unit).	1. A significant change in the trajectory of riparian and marginal vegetation on morphological units within a reach (within a resource unit).
Water quality	
1. Inorganic salts or salt ions: sodium sulphate, sodium chloride, calcium sulphate and calcium chloride.	1. 95%ile of data must not exceed the category A upper boundary as defined by the quality ecospecs.
2. Inorganic salts or salt ions: magnesium sulphate 3.	2. 95%ile of data must not exceed the category D upper boundary as defined by the quality ecospecs.
3. Inorganic salts or salt ions: magnesium chloride.	3. 95%ile of data must not exceed the category B upper boundary as defined by the quality ecospecs.
4. Nutrients: SRP (synonymous with PO4 or orthophosphate)	4. 50%ile of data must not exceed the category C upper boundary as defined by the quality ecospecs.
5. Nutrients: TIN	5. 50%ile of data must not exceed the category A/B upper boundary as defined by the quality ecospecs.
6. System variables: pH and DO	6. 95%ile of data must not exceed the category B upper boundary as defined by the quality ecospecs.
7. System variables: turbidity / SS	7. A TPC cannot be provided as no data or method is currently available. Noted as developmental issue.
Fish	
1. All 11 species expected for a C category should be present: *Labeobarbus natalensis, Labeo rubromaculatus, Amphilius natalensis (doubtful), Anguilla bengalensis, A. marmorata, A. mossambicus, Barbus anoplus etc*. (i.e. viable populations). Fish health and condition should be moderate to good.	1.Absence of any of the species.
2. All year classes of all species represented.	2. Absence or drop in abundance of any year class.
3. Maintain critical stress level below 7 to facilitate year round habitat for *L. natalensis* and passage for Anguillids:	3. Drop in abundance of any of the flow-depth and cover classes (which would relate to increased stress).

ECOSPECS	TPCs
FD = 2 FS = 3 SD = 2 SS = 2. HABITAT SUITABILITY RATING: Breeding = 3 Survival/Abundance =3 Cover =2 Health = 3 Water quality =4	
Aquatic invertebrates	
1. Ensure that no invertebrate taxon consistently dominates the fauna.	1. When any taxon has an abundance of >100 while all other taxa are <10, for two consecutive surveys.
2. Maintain presence of Perlidae.	2. Absence of Perlidae for two consecutive surveys.
3. Maintain suitable conditions for filter feeding organisms such as Simuliidae and Hydropsychidae.	3. Either is absent for two consecutive surveys.
4. Presence of *Caradina* maintained.	4. *Caradina* absent for two consecutive surveys.

11.3 ANALYSIS OF LIMITATIONS IN AVAILABLE INFORMATION

11.3.1 Water quality

Conditions to be maintained overall, but as magnesium sulphate is in an E/F category, this category will have to improve. The implementation of source-directed controls will also result in improvements to SRP and magnesium chloride. The water quality EC will probably still stay in a C category.

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Yes

Is recent information available?
No

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Yes

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Yes. Not really possible to assess as macroinvertebrate assessments not reliable due to poor habitat conditions, but elevated nutrients would lead to elevated chl-a and the production of biofilms.

Are there suitable interpretive indices available? (SASS, H-FSR)
No. Include chl-a, turbidity and DO.

Can you discern between flow and non-flow related problems?
Yes (as above Mandini industrial area).

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate.

Additional site just above the Estuary:
TPCs for the estuary were set following the quality ecospecs for IFR 16, with additional requirements. However, as monitoring at a new site will have to be instituted, i.e. the most downstream and practically accessible river site below John Ross bridge and close to the estuary (e.g. Ultimatum Tree or Havelock Farm (former Sappi monitoring sites), TPCs have been set as single values which must not be exceeded.

Due to the industrial activities of the Mandini area, a conservative approach is followed for monitoring. However, toxic substances will only be monitored when quarterly in-stream toxicity testing suggests a problem, as most industrial activities in the area do not release heavy metals. There is a concern that pesticides used in the surrounding area may enter the river and subsequently, the estuary, therefore requiring in-stream toxicity testing. Note that current monitoring does not reliably reflect in-stream conditions, especially the input of Mandini stream.

11.3.2 Fish

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Information not very suitable. Proper baseline required.

Is recent information available?
No recent information is available.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding of the requirements of the target species present is generally sufficient.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Interpretive knowledge on the habitat-flow-stress response is based on *L. natalensis* and Anguillids which are well known.
Eleven species expected to be present but proper baseline required to construct a FAII.

Are there suitable interpretive indices available? (SASS, H-FSR)
The flow stress habitat response provides a suitable interpretive index.

Can you discern between flow and non-flow related problems?
Flow and non-flow related problems can be distinguished.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate

11.3.3 Aquatic invertebrates

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Some historical data exists from a site near Mandini but the river was already impacted at that time.

Is recent information available?
Only one SASS sample, which produced poor diversity possibly as the river level had been low before the survey.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding limited due to lack of meaningful information.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Understanding is limited due to lack of meaningful information.

Are there suitable interpretive indices available? (SASS, H-FSR)
SASS is useful but does not adequately deal with flow-related issues.

Can you discern between flow and non-flow related problems?
To a limited extent as some species information exists.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Low
Due to existence of some historical information although the site was already impacted at that time. Poor recent data confuses the conclusions.

11.4 MONITORING REQUIREMENTS

The monitoring requirements are listed in the following tables.

Table 11.2 Monitoring requirements for water quality – IFR 16

BASELINE									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
Continue monthly monitoring at V5H002.	Inorganic salts, Nutrients (SRP, TIN)		Monthly		6 (samples collected simultaneously)		10 (12 if include toxics)	1	
Add turbidity to routine sampling, and record DO during sample collection.	System variables (pH, turbidity and DO)		Monthly						
Collect periphyton samples for chl-a analysis as limited data exists.	Algal abundance (chl-a)		Monthly						
LONG-TERM (5YR)									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
Continue monthly monitoring at V5H002.	Inorganic salts		Monthly		30 (samples collected simultaneously)		30	4	
Increase frequency to twice a month if there are major developments in the catchment.	Nutrients (SRP, TIN)		Monthly						
Add turbidity to routine sampling, and record DO during sample collection.	System variables (pH, turbidity and DO)		Monthly						
In-stream toxicity tests when poor biotic surveys not due to flow or habitat conditions.	In-stream toxicity		React to biotic index				4 days per series of tests.		
Collect periphyton samples for quarterly analysis (i.e. per season).	Algal abundance (chl-a)	S, W, A, Sp	4 (i.e. per season) / year		10		10		

Table 11.3 Monitoring requirements for fish – IFR 16

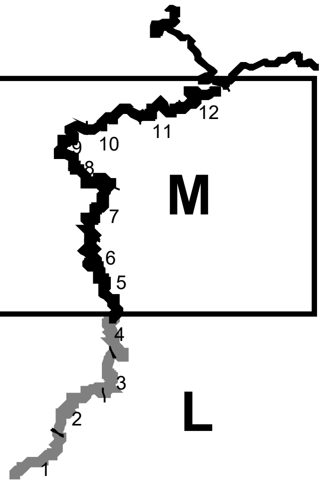
BASELINE									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Fish survey at IFR site (and section of river reach).	1, 2, 3	Low flow season	1Low flow season	1	1	0.5		0.5	
Seine sampling (10 efforts distributed over the section) and electro fishing (>40 minutes effort, 2 passes).									
Sampling quantified (CPUE, etc.)									
Determine length frequencies, age classes.									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record,), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).									

Table 11.4 Monitoring requirements for aquatic invertebrates – IFR 15

BASELINE									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
SASS5 survey at IFR 16 site.	1-2	Autumn	1		0.3	0.25		0.3	
		Winter	1		0.3				
		Spring	1		0.3				
Carry out habitat assessment at IFR 16 site.	3+4	Autumn	1		0.1				
		Winter	1		0.1				
		Spring	1		0.1				

12 RU M. IFR 3. LITTLE THUKELA RIVER (Little Thukela River)

12.1 SITE DESCRIPTION



The site is situated downstream of Winterton approximately 5km upstream from the confluence with the Thukela. The site is situated in a river valley and consists of a rapid pool section. The cross-section traverses a steep rapid consisting of large boulders, and cobbles. The left bank consists of a floodplain area with sedges. The riparian vegetation consists mostly of exotic vegetation such as black wattles. This is a mixed channel with pool/rapid morphology and bed material consists of bedrock and cobble.

12.2 ECOSPECS AND TPCs

Table 12.1 The various Ecospecs and related TPCs for each component – IFR 3

ECOSPECS	TPCs
Geomorphology	
1. To maintain the trajectory and relative location, composition and structure of morphological units within a reach (within a resource unit).	1.A significant change in the trajectory and relative location, composition and structure of morphological units within a reach (within a geomorphological zone).
Riparian vegetation	
1. To maintain the trajectory and relative location, extent, composition and structure of riparian and marginal vegetation on morphological units within a reach (within a resource unit)	1. A significant change in the trajectory of riparian and marginal vegetation on morphological units within a reach (within a resource unit).
Water quality	
1. Inorganic salts (magnesium sulphate, magnesium chloride, sodium sulphate, sodium chloride, calcium sulphate, calcium chloride) or salt ions.	1. 95%ile of data must not exceed the category A upper boundary as defined by the quality ecospecs.
2. Nutrients: SRP (synonymous with PO4 or orthophosphate).	2. 50%ile of data must not exceed the category C/D upper boundary as defined by the quality ecospecs.
3. Nutrients: TIN.	3. 50%ile of data must not exceed the category A/B upper boundary as defined by the quality ecospecs.
4. System variables: pH and DO.	4. 95%ile of data must not exceed the category B (good) upper boundary as defined by the quality ecospecs.
5. System variables: turbidity/SS.	5. A TPC cannot be provided as no data or method is currently available. Noted as developmental issue.
6. Algal abundance (chl-a).	6. Concentration must not exceed the quality ecospec for periphyton.
7. In-stream toxicity (minimum is *Daphnia*, fish and algal tests).	7. Any indication of toxicity as shown by any single test as specified in the ecospecs column (i.e. *Daphnia*, fish or algal test).
Fish	
1. All 5 species expected for a D category should be present but a considerable drop in abundance from a C category: *Labeobarbus natalensis, Labeo rubromaculatus, Amphilius natalensis, Anguilla mossambica, Barbus anoplus*. (I.e. viable populations). Fish health and condition should be moderate to good.	1.Absence of any of the species.
2. All year classes of all species represented	2. Absence or drop in abundance of any year class
3. Maintain critical stress level below 6.0 to facilitate year round riffle habitat for *A. natalensis:* FD = 2 FS = 3 SD = 4 SS = 2 HABITAT SUITABILITY RATING: • Breeding = 3 • Survival/Abundance = 3 • Cover = 3 • Health = 4 • Water quality = 4	3. Drop in abundance of any of the flow-depth and cover classes (which would relate to increased stress).

ECOSPECS	TPCs
Aquatic invertebrates	
1. To ensure that the SASS5 scores and ASPT values occur in the set range (except after major floods and during droughts). Stones biotope: SASS >120 ASPT >6.5 (in winter). Vegetation biotope: SASS >70 ASPT 5.5.	1. Stones biotope: SASS5 score <110 and ASPT <6.5 in winter. Vegetation biotope: SASS5 score <60 ASPT 5.5
2. Ensure that no invertebrate taxon consistently dominates the fauna.	2. When any taxon has an abundance of >100 while all other taxa are <10, for two consecutive surveys.
3. Maintain presence of Heptageniidae in stones biotope	3. Heptageniidae occur in an abundance <10 for two consecutive surveys.
4. 4. Maintain suitable conditions for filter feeding organisms such as Hydropsychidae and Simuliidae.	4. Hydropsychidae are absent or Simuliidae occur at abundance <10 for two consecutive surveys.
5. Flow regime to maintain the current speeds for rheophilic species	5. Abundance of rheophilic taxa in total <100 individuals.

12.3 ANALYSIS OF LIMITATIONS IN AVAILABLE INFORMATION

12.3.1 Water quality

Conditions to be maintained, therefore water quality to be a B/C category. RU M contains two QRUs, but combined due to data limitations. Confidence in the assessment is low as the gauging weir and water quality monitoring point is located just above any inputs from Winterton, and the IFR site is approximately 15km downstream of the town.

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
No

Is recent information available?
No

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Yes

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Not required as macroinvertebrate conditions good. Increases in nutrients and subsequent periphyton production will result in the formation of biofilms and affect biotic scores.

Are there suitable interpretive indices available? (SASS, H-FSR)
No. Include turbidity and DO on a regular basis, and in-stream toxicity testing during low flows due to pesticide use in the area.

Can you discern between flow and non-flow related problems?
Yes

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Low - Moderate

12.3.2 Fish

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Information not very suitable. Proper baseline required.

Is recent information available?
No recent information is available.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding of the requirements of the target species present is generally sufficient.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Interpretive knowledge on the habitat-flow-stress response is based on *A. natalensis* which is well known.
Five species expected to be present but proper baseline required to construct a FAII.

Are there suitable interpretive indices available? (SASS, H-FSR)
The flow stress habitat response provides a suitable interpretive index.

Can you discern between flow and non-flow related problems?
Flow and non-flow related problems can be distinguished.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate

12.3.3 Aquatic invertebrates

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
No historical data from this reach but is from the main Thukela. .

Is recent information available?
Only one survey in 2001.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding is at a crude level – species level information and knowledge of species biology would be necessary to get a better understanding.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues).
Understanding is at a crude level – species level information and knowledge of species biology would be necessary to better understand habitat-flow-stress responses. Understanding of non-flow related issues (e.g. water quality) is better.

Are there suitable interpretive indices available? (SASS, H-FSR)
SASS is useful but does not adequately deal with flow-related issues.

Can you discern between flow and non-flow related problems?
Only to a limited extent.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate
The presence of Heptageniids, a sensitive flow dependent species, gives a clear indication of the condition of this site.

12.4 MONITORING REQUIREMENTS

The monitoring requirements are listed in the following tables.

Table 12.2 Monitoring requirements for water quality – IFR 3

BASELINE

ACTION	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Continue monthly monitoring at V1H010.	Inorganic salts		Monthly		6.5 (samples collected simultaneously)		7		1.5
Increase frequency to twice a month if there are major developments in the catchment.	Nutrients (SRP, TIN)		Monthly						
Add turbidity to routine sampling and DO during sample collection.	System variables (pH, turbidity and DO)		Monthly						
Collect periphyton samples at **IFR site** for chl-a analysis as no baseline exists.	Algal abundance (chl-a)		Monthly						
In-stream toxicity tests with a water sample taken from the **IFR site** at time of pesticide use in the area and low flows, or in response to a biotic trigger.	In-stream toxicity		2 (estimate)				4 days per series of tests, i.e. 8		

LONG-TERM (5YR)

Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Continue monthly monitoring at V1H010.	Inorganic salts		Monthly		32 (samples collected simultaneously)		30	4	
Increase frequency to twice a month if there are major developments in the catchment.	Nutrients (SRP, TIN)		Monthly						
Add turbidity and DO to routine sampling.	System variables (pH, turbidity and DO)		Monthly						
In-stream toxicity tests with a water sample taken from the IFR site when poor biotic surveys not due to flow or habitat conditions.	In-stream toxicity		React to biotic index				4 days per series of tests.		
Collect periphyton samples at IFR s**ite** for quarterly analysis (i.e. per season).	Algal abundance (chl-a)	S, W, A, Sp	4 (i.e. per season) / year		10		10		

Table 12.3 Monitoring requirements for fish – IFR 3

BASELINE

Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Fish survey at IFR site (and section of river reach).	1, 2, 3	Low flow season	1 Low flow season	1	1	0.5		0.5	
Seine sampling (10 efforts distributed over the section) and electro fishing (>40 minutes effort, 2 passes).									
Sampling quantified (CPUE, etc.).									
Determine length frequencies, age classes.									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).									

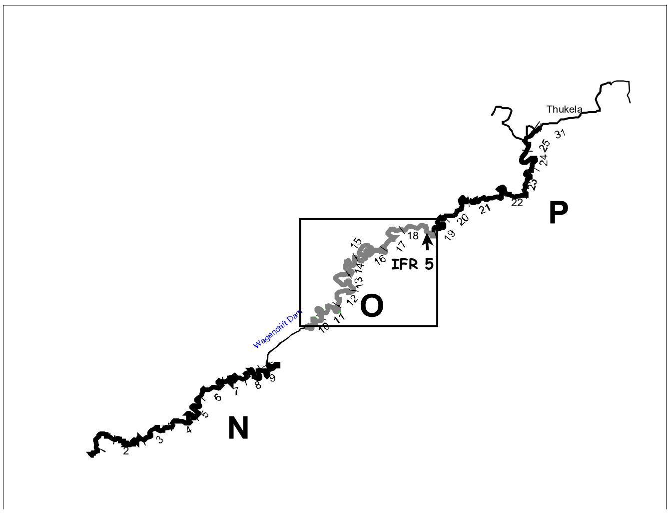
LONG-TERM (5YR)

Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Fish survey at IFR site (and section of river reach).	1, 2, 3	Low flow season	1 Low flow season for 3 years during the baseline phase		2	0.5		0.5	
Seine sampling (and electro fishing (>40 minutes or/or 2 passes).									
Sampling quantified (CPUE, etc.).									
Determine length frequencies, age classes.									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).									

Table 12.4 Monitoring requirements for aquatic invertebrates – IFR 3

BASELINE									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
SASS5 survey at IFR 3 site.	1-5	Autumn	1		0.3	0.25		0.3	
		Winter	1		0.3				
		Spring	1		0.3				
Carry out habitat assessment at IFR 3 site.	4-5	Autumn	1		0.1				
		Winter	1		0.1				
		Spring	1		0.1				
LONG-TERM (5YR)									
Action	Ecospec	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
SASS5 survey at IFR1 site.	1-5					0.5		1.5	
		Winter	5		1.5				
Carry out habitat assessment at IFR 1 site.	4-5	Winter	5		1.5				

13 RU O. IFR 5. WEENEN NATURE RESERVE (Bushman's river)



13.1 SITE DESCRIPTION

The site is situated in the Bushmans River just upstream of the downstream border of the Weenen Nature Reserve. This is a mixed channel with pool/riffle morphology and with bed material consisting of cobbles and boulders interspersed with sand and gravel. This is a high confidence site that formed part of the previous IFR studies and the site with the associated habitat modelling that was undertaken as part of the sediment transport modelling will be used as is.

13.2 ECOSPECS AND TPCs

Table 13.1 The various Ecospecs and related TPCs for each component – IFR 5

ECOSPECS	TPCs
Geomorphology	
1. To maintain the trajectory and relative location, composition and structure of morphological units within a reach (within a resource unit).	1. A significant change in the trajectory and relative location, composition and structure of morphological units within a reach (within a geomorphological zone).
Riparian vegetation	
1. To maintain the trajectory and relative location, extent, composition and structure of riparian and marginal vegetation on morphological units within a reach (within a resource unit)	1. A significant change in the trajectory of riparian and marginal vegetation on morphological units within a reach (within a resource unit).
Water quality	
1. Inorganic salts or salt ions: sodium sulphate, sodium chloride, calcium sulphate and calcium chloride.	1. 95%ile of data must not exceed the category A upper boundary as defined by the quality ecospecs.
2. Inorganic salts or salt ions: magnesium sulphate.	2. 95%ile of data must not exceed the category C upper boundary as defined by the quality ecospecs.
3. Inorganic salts or salt ions: magnesium chloride.	3. 95%ile of data must not exceed the category B upper boundary as defined by the quality ecospecs.
4. Nutrients: SRP (synonymous with PO4 or orthophosphate).	4. 50%ile of data must not exceed the category C upper boundary as defined by the quality ecospecs.
5. Nutrients: TIN.	5. 50%ile of data must not exceed the category A/B upper boundary as defined by the quality ecospecs.
6. System variables: pH and DO	6. 95%ile of data must not exceed the category B upper boundary as defined by the quality ecospecs.
7. System variables: turbidity/SS.	7. A TPC cannot be provided as no data or method is currently available. Noted as developmental issue.
8. Algal abundance (chl-a)	8. Concentration must not exceed the quality ecospec for periphyton.
9. In-stream toxicity (minimum is *Daphnia*, fish and algal tests).	9. Any indication of toxicity as shown by any single test as specified in the ecospecs column (i.e. *Daphnia*, fish or algal test).

ECOSPECS	TPCs
10. Toxic substances (e.g. heavy metals and ammonia).	10. 95%ile of data must not exceed the CEV.
Fish	
1. All 4 species expected for a C category should be present. *Anguilla mossambica, Anguilla bengalensis, Labeobarbus natalensis, Barbus anoplus* (i.e. viable populations). Fish health and condition should be moderate to good.	1.Absence of any of the species.
2. All year classes of all species represented.	2. Absence or drop in abundance of any year class.
3. Maintain critical stress level below 7 to facilitate year round survival and health of *L. natalensis:* FD = 2 FS = 3 SD = 3 SS = 4. HABITAT SUITABILITY RATING: Breeding = 4 Survival/Abundance =3 Cover =4 Health = 4 Water quality =4	3. Drop in abundance of any of the flow-depth and cover classes (which would relate to increased stress).
Aquatic invertebrates	
1. To ensure that the SASS5 scores and ASPT values occur in the set range (except after major floods and during droughts). Stones biotope: SASS >100 ASPT >6.5 (in winter). Vegetation biotope: SASS >80 ASPT 6.	1. Stones biotope SASS5 score <90 and ASPT <6 in winter. Vegetation SASS5 score <70 ASPT 5.5.
2. Maintain presence of Baetidae in stones biotope.	2. Baetidae occur in an abundance <10 for two consecutive surveys.
3. Maintain connectivity with marginal vegetation biotope.	3. All vegetation dwelling families absent from entire sample on two consecutive surveys.
4. Flow regime to maintain the current speeds for rheophilic species.	4. Abundance of rheophilic taxa in total <10 individuals.
5. Flow regime to maintain the current diversity of biotopes.	5. Either SIC, SOOC or Marginal Vegetation biotopes are lost to invertebrates

13.3 ANALYSIS OF LIMITATIONS IN AVAILABLE INFORMATION

13.3.1 Water quality

Water quality is currently in a B/C category, but due to the industrial component of Estcourt's sewage effluent, conditions may deteriorate into a lower category during the dry season. Water quality will therefore have to be managed to stay in a B/C category. This is particularly important as data confidence is low to moderate, and the gauging weir is above the town and IFR site, thereby reducing the confidence of the assessment.

Is recent information available?
No.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Yes

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
No

Are there suitable interpretive indices available? (SASS, H-FSR)
No, as little temperature data exists, and turbidity and oxygen not monitored.

Can you discern between flow and non-flow related problems?
No, as dam impacts cannot be assessed.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Low.

13.3.2 Fish

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Information not very suitable. Proper baseline required.

Is recent information available?
No recent information is available.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding of the requirements of the target species present is generally sufficient.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Interpretive knowledge on the habitat-flow-stress response is based on *A. natalensis* which is well known. Four species expected to be present but proper baseline required to construct a FAII.

Are there suitable interpretive indices available? (SASS, H-FSR)
The flow stress habitat response provides a suitable interpretive index.

Can you discern between flow and non-flow related problems?
Flow and non-flow related problems can be distinguished.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate

13.3.3 Aquatic invertebrates

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Information is inadequate and nor is there directly comparable information from neighbouring catchments. .

Is recent information available?
No

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding is at a very low level – even family level information is not available.
Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)

Understanding is at a very low level as even family level information is not available. Species level information and knowledge of species biology would be necessary to better understand habitat-flow-stress responses. Understanding of non-flow related issues (e.g. water quality) is better.

Are there suitable interpretive indices available? (SASS, H-FSR)
SASS is useful but does not adequately deal with flow-related issues.

Can you discern between flow and non-flow related problems?
Only to a limited extent.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Low, due to inadequate real data.

13.4 MONITORING REQUIREMENTS

The monitoring requirements are listed in the following tables.

Table 13.2 Monitoring requirements for water quality – IFR 5

BASELINE									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
Institute bimonthly monitoring at V7H012.	Inorganic salts, Nutrients (SRP, TIN)		Bimonthly		10 (samples collected simultaneously)		12	1	
Add turbidity to routine sampling, and record DO during sample collection.	System variables (pH, turbidity and DO)		Bimonthly						
Collect periphyton samples for chl-a analysis as no baseline exists.	Algal abundance (chl-a)		Monthly						
	Toxic substances (e.g. heavy metals and ammonia)		Monthly						

LONG-TERM (5YR)									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
Continue monthly monitoring at V6H004.	Inorganic salts		Monthly		30 (samples collected simultaneously)		30	6	
Increase frequency to twice a month if there are major developments in the catchment.	Nutrients (SRP, TIN)		Monthly						
Add turbidity to routine sampling, and record DO during sample collection.	System variables (pH, turbidity and DO)		Monthly						
In-stream toxicity tests when poor biotic surveys not due to flow or habitat conditions.	In-stream toxicity		React to biotic index				4 days per series of tests.		
	Toxic substances (e.g. heavy metals and ammonia)		Monthly				10		
Collect periphyton samples for quarterly analysis (i.e. per season).	Algal abundance (chl-a)	S, W, A, Sp	4 (i.e. per season) / year				10		

Table 13.3 Monitoring requirements for fish – IFR 5

BASELINE									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
Fish survey at IFR site (and section of river reach).	1, 2, 3	Low flow season	1 Low flow season	1	1	0.5		0.5	
Seine sampling (10 efforts distributed over the section) and electro fishing (>40 minutes effort, 2 passes).									
Sampling quantified (CPUE, etc.).									
Determine length frequencies, age classes									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).									
LONG-TERM (5YR)									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
Fish survey at IFR site (and section of river reach).	1, 2, 3	Low flow season	1 Low flow season for 3 years during the baseline phase		2	0.5		0.5	
Seine sampling (and electro fishing (>40 minutes or/or 2 passes).									
Sampling quantified (CPUE, etc.).									
Determine length frequencies, age classes.									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).									

Table 13.4 Monitoring requirements for aquatic invertebrates – IFR 5

<table>
<tr><th colspan="10">BASELINE</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td rowspan="3">SASS5 survey at IFR 5 site.</td><td rowspan="3">1-4</td><td>Autumn</td><td>1</td><td rowspan="6"></td><td>0.3</td><td rowspan="6">0.25</td><td rowspan="6"></td><td rowspan="6">0.3</td><td rowspan="6"></td></tr>
<tr><td>Winter</td><td>1</td><td>0.3</td></tr>
<tr><td>Spring</td><td>1</td><td>0.3</td></tr>
<tr><td rowspan="3">Carry out habitat assessment at IFR 5 site.</td><td rowspan="3">5</td><td>Autumn</td><td>1</td><td>0.1</td></tr>
<tr><td>Winter</td><td>1</td><td>0.1</td></tr>
<tr><td>Spring</td><td>1</td><td>0.1</td></tr>
<tr><th colspan="10">LONG-TERM (5YR)</th></tr>
<tr><th rowspan="3">ACTION</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td rowspan="3">SASS5 survey at IFR 5 site.</td><td rowspan="3">1-4</td><td></td><td></td><td rowspan="3"></td><td></td><td rowspan="4">0.5</td><td rowspan="4"></td><td rowspan="4">1.5</td><td rowspan="4"></td></tr>
<tr><td>Winter</td><td>5</td><td>1.5</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>Carry out habitat assessment at IFR 5 site.</td><td>5</td><td>Winter</td><td>5</td><td></td><td>1.5</td></tr>
</table>

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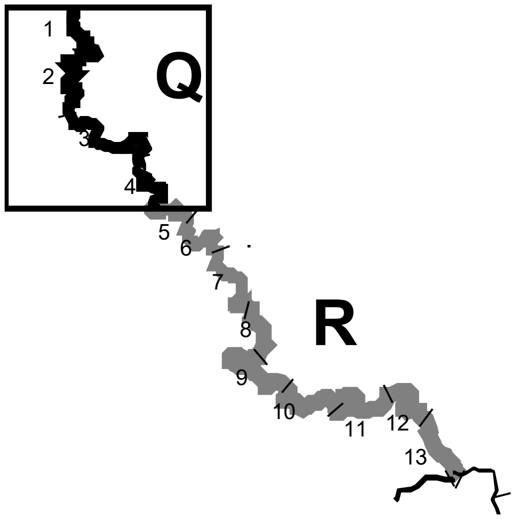
14 RU Q. IFR 7. UPPER SUNDAYS (Sunday River)

14.1 SITE DESCRIPTION

The site is selected upstream of the Enambithi Regional Water Supply in Resource Unit Q. The site is characterised by a mixed channel with pool/riffle morphology. The bed material consists of bedrock and cobbles.



14.2 ECOSPECS AND TPCs

Table 14.1 The various Ecospecs and related TPCs for each component – IFR 7

ECOSPECS	TPCs
Geomorphology	
1. To maintain the trajectory and relative location, composition and structure of morphological units within a reach (within a resource unit).	1. A significant change in the trajectory and relative location, composition and structure of morphological units within a reach (within a geomorphological zone).
Riparian vegetation	
1. To maintain the trajectory and relative location, extent, composition and structure of riparian and marginal vegetation on m morphological units within a reach (within a resource unit)	1. A significant change in the trajectory of riparian and marginal vegetation on morphological units within a reach (within a resource unit).
Water quality	
1. Inorganic salts or salt ions: magnesium chloride, sodium chloride, calcium sulphate and calcium chloride	1. 95%ile of data must not exceed the category A upper boundary as defined by the quality ecospecs.
2. Inorganic salts or salt ions: magnesium sulphate	2. 95%ile of data must not exceed the category D upper boundary as defined by the quality ecospecs.
3. Inorganic salts or salt ions: sodium sulphate	3. 95%ile of data must not exceed the category B upper boundary as defined by the quality ecospecs.
4. Nutrients: SRP (synonymous with PO4 or orthophosphate)	4. 50%ile of data must not exceed the category C upper boundary as defined by the quality ecospecs.
5. Nutrients: TIN	5. 50%ile of data must not exceed the category B upper boundary as defined by the quality ecospecs.
6. System variables: pH and DO	6. 95%ile of data must not exceed the category B upper boundary as defined by the quality ecospecs
7. System variables: turbidity / SS	7. A TPC cannot be provided as no data or method is currently available. Noted as developmental issue.
8. Algal abundance (chl-a)	8. Concentration must not exceed the quality ecospec for periphyton.
9. In-stream toxicity (minimum is *Daphnia*, fish and algal tests)	9. Any indication of toxicity as shown by any single test as specified in the ecospecs column (i.e. *Daphnia*, fish or algal test).
Fish	
1. All 5 species expected for a B category should be present: *Labeobarbus natalensis, Labeo rubromaculatus, Anguilla mossambica, Barbus anoplus & Clarias gariepinus*. (I.e. viable populations). Fish health and condition should be moderate to good.	1. Absence of any of the species.
2. All year classes of all species represented.	2. Absence or drop in abundance of any year class.
3. Maintain critical stress level below 7.5 to facilitate year round habitat and cover for *L. natalensis* and *L. rubromaculatus:* FD = 1 FS = 2 SD = 4 SS = 3 HABITAT SUITABILITY RATING:	3. Drop in abundance of any of the flow-depth and cover classes (which would relate to increased stress).

ECOSPECS	TPCs
Breeding = 2 Survival/Abundance =1 Cover =3 Health = 3 Water quality =2	
Aquatic invertebrates	
1. To ensure that the SASS5 scores and ASPT values occur in the set range (except after major floods and during droughts). Stones biotope: SASS >130 ASPT >6 (in winter). Vegetation biotope: SASS >35.	1. Stones biotope SASS5 score <110 and ASPT <5.5 in winter. Vegetation SASS5 score <25.
2. Ensure that no invertebrate taxon consistently dominates the fauna.	2. When any taxon has an abundance of >100 while all other taxa are <10, for two consecutive surveys.
3. Maintain presence of diverse mayfly taxa in stones biotope.	3. Less than 4 families of mayflies occur for two consecutive surveys.
4. Maintain suitable conditions for filter feeding organisms such as Hydropsychidae and Simuliidae.	4. Hydropsychidae or Simuliidae occur at abundance <10 for two consecutive surveys.
5. Maintain fine leafed aquatic vegetation.	5. Aquatic vegetation absent from entire sample on two consecutive surveys.
6. Flow regime to maintain the current speeds for rheophilic species.	6. Abundance of rheophilic taxa in total <100 individuals.
7. Flow regime to maintain the current diversity of biotopes.	7. Either SIC, SOOC or Aquatic Vegetation biotopes are lost to invertebrates

14.3 ANALYSIS OF LIMITATIONS IN AVAILABLE INFORMATION

14.3.1 Water quality

Conditions to be improved as magnesium sulphate is in an E/F category. SRP should be improved to a C category. These improvements should improve the water quality EC to a B/C category (currently a C category).

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Yes

Is recent information available?
No

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
No

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Yes. Nutrients (possibly resulting in elevated chl-a levels) and sulphate from mining activities.

Are there suitable interpretive indices available? (SASS, H-FSR)
No. Include chl-a, turbidity and DO.

Can you discern between flow and non-flow related problems?
Yes

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Low – Moderate

14.3.2 Fish

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Information not very suitable. Proper baseline required.

Is recent information available?
No recent information is available.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding of the requirements of the target species present is generally sufficient.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Interpretive knowledge on the habitat-flow-stress response is based on *L. natalensis* and *L. rubromaculatus* which are well known.
Five species expected to be present but proper baseline required to construct a FAII.

Are there suitable interpretive indices available? (SASS, H-FSR)
The flow stress habitat response provides a suitable interpretive index

Can you discern between flow and non-flow related problems?
Flow and non-flow related problems can be distinguished.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate

14.3.3 Aquatic invertebrates

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Some historical information is available at species level, but not from the same site .

Is recent information available?
Only one SASS survey.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding is at a crude level – species level information and knowledge of species biology would be necessary for a better understanding.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Understanding is at a crude level – species level information and knowledge of species biology would be necessary to better understand habitat-flow-stress responses. Understanding of non-flow related issues (e.g. water quality) is better.

Are there suitable interpretive indices available? (SASS, H-FSR)
SASS is useful but does not adequately deal with flow-related issues.

Can you discern between flow and non-flow related problems?
Only to a limited extent.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate
Species information would be necessary to gain better understanding. There is also no understanding of the natural variability in the system.

14.4 MONITORING REQUIREMENTS

The monitoring requirements are listed in the following tables.

Table 14.2 Monitoring requirements for water quality – IFR 7

<table>
<tr><th colspan="10">BASELINE</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Institute bimonthly monitoring at V6H004.</td><td>Inorganic salts, Nutrients (SRP, TIN)</td><td rowspan="3"></td><td>Bimonthly</td><td rowspan="3"></td><td rowspan="3">10 (samples collected simultaneously)</td><td rowspan="3"></td><td rowspan="3">10</td><td rowspan="3">1</td><td rowspan="3"></td></tr>
<tr><td>Add turbidity to routine sampling, and record DO during sample collection.</td><td>System variables (pH, turbidity and DO)</td><td>Bimonthly</td></tr>
<tr><td>Collect periphyton samples for chl-a analysis as no baseline exists.</td><td>Algal abundance (chl-a)</td><td>Monthly</td></tr>
<tr><th colspan="10">LONG-TERM (5YR)</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Continue monthly monitoring at V6H004.</td><td>Inorganic salts</td><td></td><td>Monthly</td><td rowspan="5"></td><td rowspan="4">30 (samples collected simultaneously)</td><td rowspan="5"></td><td rowspan="3">30 T</td><td rowspan="5"></td><td rowspan="5">4 (6 if include toxics)</td></tr>
<tr><td>Increase frequency to twice a month if there are major developments in the catchment.</td><td>Nutrients (SRP, TIN)</td><td></td><td>Monthly</td></tr>
<tr><td>Add turbidity to routine sampling, and record DO during sample collection.</td><td>System variables (pH, turbidity and DO)</td><td></td><td>Monthly</td></tr>
<tr><td>In-stream toxicity tests when poor biotic surveys not due to flow or habitat conditions.</td><td>In-stream toxicity</td><td></td><td>React to biotic index</td><td>4 days per series of tests.</td></tr>
<tr><td>Collect periphyton samples for quarterly analysis (i.e. per season).</td><td>Algal abundance (chl-a)</td><td>S, W, A, Sp</td><td>4 (i.e. per season) / year</td><td>10</td><td>10</td></tr>
</table>

Table 14.3 Monitoring requirements for fish – IFR 7

BASELINE

Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Fish survey at IFR site (and section of river reach).	1, 2, 3	Low flow season	1 Low flow season	1	1	0.5		0.5	
Seine sampling (10 efforts distributed over the section) and electro fishing (>40 minutes effort, 2 passes).									
Sampling quantified (CPUE, etc.).									
Determine length frequencies, age classes.									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).									

LONG-TERM (5YR)

Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Fish survey at IFR site (and section of river reach).	1, 2, 3	Low flow season	1 Low flow season for 3 years during the baseline phase		2	0.5		0.5	
Seine sampling (and electro fishing (>40 minutes or/or 2 passes).									
Sampling quantified (CPUE, etc.).									
Determine length frequencies, age classes.									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).									

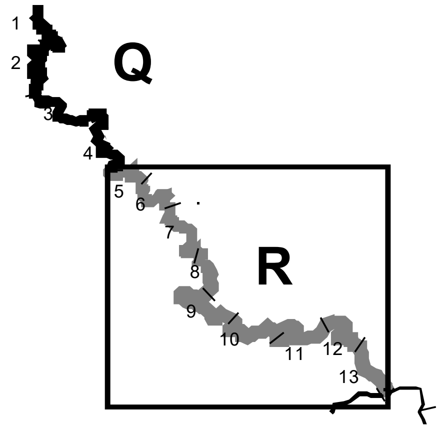
Table 14.4 Monitoring requirements for aquatic invertebrates – IFR 7

BASELINE									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
SASS5 survey at IFR 7 site.	1-4 +6	Autumn	1		0.3	0.25		0.3	
		Winter	1		0.3				
		Spring	1		0.3				
Carry out habitat assessment at IFR 7 site.	5+7	Autumn	1		0.1				
		Winter	1		0.1				
		Spring	1		0.1				
LONG-TERM (5YR)									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
SASS5 survey at IFR 7 site.	1-4 +6					0.5		1.5	
		Winter	5		1.5				
Carry out habitat assessment at IFR 7 site	5+7	Winter	5		1.5				

15 RU R. IFR 8. LOWER SUNDAYS (Sundays River)

15.1 SITE DESCRIPTION

The site is situated near the Veil of Hope in RU R. The site is characterised by a mixed channel with pool/riffle morphology. The bed material consists of cobbles and gravel.



15.2 ECOSPECS AND TPCs

Table 15.1 The various Ecospecs and related TPCs for each component – IFR 8

ECOSPECS	TPCs
Geomorphology	
1. To maintain the trajectory and relative location, composition and structure of morphological units within a reach (within a resource unit).	1.A significant change in the trajectory and relative location, composition and structure of morphological units within a reach (within a geomorphological zone).
Riparian vegetation	
1. To maintain the trajectory and relative location, extent, composition and structure of riparian and marginal vegetation on morphological units within a reach (within a resource unit)	1. A significant change in the trajectory of riparian and marginal vegetation on morphological units within a reach (within a resource unit).
Fish	
1. All 10 species expected for a C category should be present: *Amphilius natalensis*, *Labeobarbus natalensis, Labeo rubromaculatus, Anguilla mossambica, Barbus anoplus, Clarias gariepinus etc*. (I.e. viable populations). Fish health and condition should be moderate to good.	1.Absence of any of the species.
2. All year classes of all species represented.	2. Absence or drop in abundance of any year class.
3. Maintain critical stress level below 7.5 to facilitate year round riffle habitat for *A. natalensis* and habitat and cover for *L. natalensis* and *L. rubromaculatus:* FD = 0 FS = 1 SD = 2 SS = 4. HABITAT SUITABILITY RATING: Breeding = 1 Survival/Abundance =1 Cover =1 Health = 4 Water quality =3	3. Drop in abundance of any of the flow-depth and cover classes (which would relate to increased stress).
Aquatic invertebrates	
1. To ensure that the SASS5 scores and ASPT values occur in the set range (except after major floods and during droughts). Stones biotope: SASS >100 ASPT >6 (in winter). Vegetation biotope: SASS >30.	1. Stones biotope SASS5 score <90 and ASPT <5.5 in winter. Vegetation SASS5 score <20.
2. Ensure that no invertebrate taxon consistently dominates the fauna.	2. When any taxon has an abundance of >100 while all other taxa are <10, for two consecutive surveys.
3. Maintain presence of diverse mayfly taxa in stones biotope.	3. Less than 3 families of mayflies occur for two consecutive surveys.
4. Maintain suitable conditions for filter feeding organisms such as Hydropsychidae and Simuliidae.	4. Hydropsychidae or Simuliidae absent for two consecutive surveys.
5. Flow regime to maintain the current speeds for rheophilic species.	5. Abundance of rheophilic taxa in total <100 individuals.

15.3 ANALYSIS OF LIMITATIONS IN AVAILABLE INFORMATION

15.3.1 Fish

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Information not very suitable. Proper baseline required.

Is recent information available?
No recent information is available.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding of the requirements of the target species present is generally sufficient.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Interpretive knowledge on the habitat-flow-stress response is based on *A. natalensis, L. natalensis* and *L. rubromaculatus* which are well known.
Ten species expected to be present but proper baseline required to construct a FAII.

Are there suitable interpretive indices available? (SASS, H-FSR)
The flow stress habitat response provides a suitable interpretive index.

Can you discern between flow and non-flow related problems?
Flow and non-flow related problems can be distinguished.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate

15.3.2 Aquatic invertebrates

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
No data from this resource unit. Historical data from the neighbouring Thukela River provides some information (1960).

Is recent information available?
Yes, but only one SASS survey (2001).

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding is at a crude level – species level information and knowledge of species biology would be necessary for a better understanding.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Understanding is at a crude level – species level information and knowledge of species biology would be necessary to better understand habitat-flow-stress responses. Understanding of non-flow related issues (e.g. water quality) is better.

Are there suitable interpretive indices available? (SASS, H-FSR)
SASS is useful but does not adequately deal with flow-related issues.

Can you discern between flow and non-flow related problems?
Only to a limited extent.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Low.
Due to absence of data to show the natural variability and inadequate species information.

15.4 MONITORING REQUIREMENTS

The monitoring requirements are listed in the following tables.

Table 15.2 Monitoring requirements for fish – IFR 8

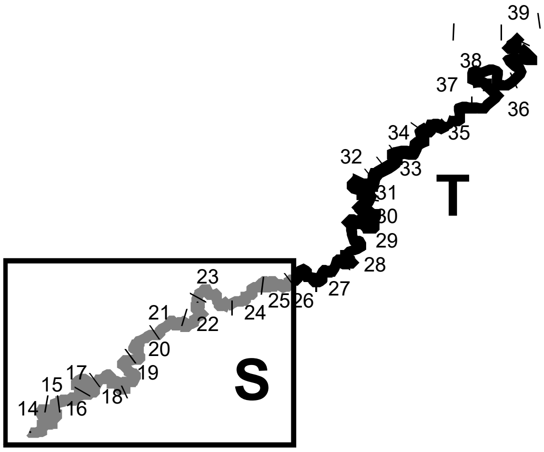
BASELINE									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Fish survey at IFR site (and section of river reach).	1, 2, 3	Low flow season	1 low flow season	1	1	0.5		0.5	
Seine sampling (10 efforts distributed over the section) and electro fishing (>40 minutes effort, 2 passes).									
Sampling quantified (CPUE, etc.).									
Determine length frequencies, age classes.									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming)									

Table 15.3 Monitoring requirements for aquatic invertebrates – IFR 8

BASELINE									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
SASS5 survey at IFR 8 site.	1-5	Autumn	1		0.3	0.25		0.3	
		Winter	1		0.3				
		Spring	1		0.3				
Carry out habitat assessment at IFR 8 site.	4+5	Autumn	1		0.1				
		Winter	1		0.1				
		Spring	1		0.1				

16 RU S. IFR 10. CARAVAN PARK (Mooi River)

16.1 SITE DESCRIPTION



The site is situated in the Mooi River Caravan Park, immediately downstream of the town of Mooi River and the confluence with the Little Mooi.

16.2 ECOSPECS AND TPCs

Table 16.1 The various Ecospecs and related TPCs for each component – IFR 10

ECOSPECS	TPCs
Geomorphology	
1. To maintain the trajectory and relative location, composition and structure of morphological units within a reach (within a resource unit).	1. A significant change in the trajectory and relative location, composition and structure of morphological units within a reach (within a geomorphological zone).
Riparian vegetation	
1. To maintain the trajectory and relative location, extent, composition and structure of riparian and marginal vegetation on morphological units within a reach (within a resource unit)	1. A significant change in the trajectory of riparian and marginal vegetation on morphological units within a reach (within a resource unit).
Water quality	
1. Inorganic salts (magnesium sulphate, magnesium chloride, sodium sulphate, sodium chloride, calcium sulphate, calcium chloride) or salt ions.	1. 95%ile of data must not exceed the category A upper boundary as defined by the quality ecospecs.
2. Nutrients: SRP (synonymous with PO4 or orthophosphate).	2. 50%ile of data must not exceed the category C upper boundary as defined by the quality ecospecs.
3. Nutrients: TIN.	3. 50%ile of data must not exceed the category A/B upper boundary as defined by the quality ecospecs.
4. System variables: pH and DO.	4. 95%ile of data must not exceed the category B (good) upper boundary as defined by the quality ecospecs.
5. System variables: turbidity / SS	5. A TPC cannot be provided as no data or method is currently available. Noted as developmental issue.
6. Algal abundance (chl-a)	6. Concentration must not exceed the quality ecospec for periphyton.
7. In-stream toxicity (minimum is *Daphnia*, fish and algal tests)	7. Any indication of toxicity as shown by any single test as specified in the ecospecs column (i.e. *Daphnia*, fish or algal test).
Fish	
1. All 4 species expected for a C/D category should be present. *Anguilla mossambica, Barbus anoplus, B. natalensis* and *Amphilius natalensis.* With the possible exception of the latter (i.e. viable populations). Fish health and condition should be moderate to good.	1.Absence of any of the species.
2. All year classes of all species represented.	2. Absence or drop in abundance of any year class.
3. Maintain critical stress level below 7 to facilitate year round survival and health of *L. natalensis,* perhaps riffle habitat for *A. natalensis:* FD = 1 FS = 1 SD = 3 SS = 4. HABITAT SUITABILITY RATING: Breeding = 2 Survival/Abundance =2 Cover =3 Health = 3 Water quality =3	3. Drop in abundance of any of the flow-depth and cover classes (which would relate to increased stress).

ECOSPECS	TPCs
Aquatic invertebrates	
1. To ensure that the SASS5 scores and ASPT values occur in the set range (except after major floods and during droughts). Stones biotope: SASS >120 ASPT >6 (in winter).	1. Stones biotope SASS5 score <110 and ASPT <5.5 in winter.
2. Ensure that no invertebrate taxon consistently dominates the fauna.	2. When any taxon has an abundance of >100 while all other taxa are <10, for two consecutive surveys.
3. Maintain presence of diverse mayfly taxa in stones biotope.	3. At most, less than 2 families of mayflies may be lost/missed between any two consecutive surveys.
4. Maintain suitable conditions for filter feeding organisms such as Hydropsychidae.	4. Hydropsychidae absent for two consecutive surveys.
5. Flow regime to maintain the current speeds for rheophilic species	5. Abundance of rheophilic taxa in total <100 individuals

16.3 ANALYSIS OF LIMITATIONS IN AVAILABLE INFORMATION

16.3.1 Water quality

Conditions to be maintained at a B category for water quality.

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Yes

Is recent information available?
No

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Yes

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Yes. Nutrients (possibly resulting in elevated chl-a levels).

Are there suitable interpretive indices available? (SASS, H-FSR)
No. Include chl-a, turbidity and DO.

Can you discern between flow and non-flow related problems?
Yes

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate – high

16.3.2 Fish

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Information not very suitable. Proper baseline required.

Is recent information available?
No recent information is available.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding of the requirements of the target species present is generally sufficient.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Interpretive knowledge on the habitat-flow-stress response is based on *L. natalensis* and *A. natalensis* which are well known.
Four species expected to be present but proper baseline required to construct a FAII.

Are there suitable interpretive indices available? (SASS, H-FSR)
The flow stress habitat response provides a suitable interpretive index.

Can you discern between flow and non-flow related problems?
Flow and non-flow related problems can be distinguished.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate

16.3.3 Aquatic invertebrates

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Good historical and recent data is available.

Is recent information available?
Yes including species surveys in 1995.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding reasonable due to presence of species information.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Understanding is reasonable due to presence of species information.

Are there suitable interpretive indices available? (SASS, H-FSR)
SASS is useful but does not adequately deal with flow-related issues.

Can you discern between flow and non-flow related problems?
In many cases yes because species information exists.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
High/Moderate
Due to existence of historical and species information.

16.4 MONITORING REQUIREMENTS

The monitoring requirements are listed in the following tables.

Table 16.2 Monitoring requirements for water quality – IFR 10

<table>
<tr><th colspan="10">BASELINE</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Continue monthly monitoring at V2H002.</td><td>Inorganic salts</td><td rowspan="4"></td><td>Monthly</td><td rowspan="4"></td><td rowspan="4">6 (samples collected simultaneously)</td><td rowspan="4"></td><td rowspan="4">6</td><td rowspan="4">1</td><td rowspan="4"></td></tr>
<tr><td>Increase frequency to twice a month if there are major developments in the catchment.</td><td>Nutrients (SRP, TIN)</td><td>Monthly</td></tr>
<tr><td>Add turbidity and DO to routine sampling.</td><td>System variables (pH, turbidity, DO)</td><td>Monthly</td></tr>
<tr><td>Collect periphyton samples for chl-a analysis as no baseline exists.</td><td>Algal abundance (chl-a)</td><td>Monthly</td></tr>
<tr><th colspan="10">LONG-TERM (5YR)</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Continue monthly monitoring at V2H002.</td><td>Inorganic salts</td><td></td><td>Monthly</td><td rowspan="5"></td><td rowspan="4">30 (samples collected simultaneously)</td><td rowspan="5"></td><td rowspan="3">30</td><td rowspan="5">4</td><td rowspan="5"></td></tr>
<tr><td>Increase frequency to twice a month if there are major developments in the catchment.</td><td>Nutrients (SRP, TIN)</td><td></td><td>Monthly</td></tr>
<tr><td>Add turbidity and DO to routine sampling.</td><td>System variables (pH, turbidity, DO)</td><td></td><td>Monthly</td></tr>
<tr><td>In-stream toxicity tests when poor biotic surveys not due to flow or habitat conditions.</td><td>In-stream toxicity</td><td></td><td>React to biotic index</td><td>4 days per series of tests</td></tr>
<tr><td>Collect periphyton samples for quarterly analysis.</td><td>Algal abundance (chl-a)</td><td>S, W, A, Sp</td><td>4 (i.e. per season) / year</td><td></td><td></td></tr>
</table>

Table 16.3 Monitoring requirements for fish – IFR 10

BASELINE

Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Fish survey at IFR site (and section of river reach). Seine sampling (10 efforts distributed over the section) and electro fishing (>40 minutes effort, 2 passes). Sampling quantified (CPUE, etc.). Determine length frequencies, age classes. Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data. Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).	1, 2, 3	Low flow season	1 Low flow season	1	1	0.5		0.5	

LONG-TERM (5YR)

Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Fish survey at IFR site (and section of river reach). Seine sampling (and electro fishing (>40 minutes or/or 2 passes). Sampling quantified (CPUE, etc.). Determine length frequencies, age classes. Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data. Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).	1, 2, 3	Low flow season	1 Low flow season for 3 years during the baseline phase		2	0.5		0.5	

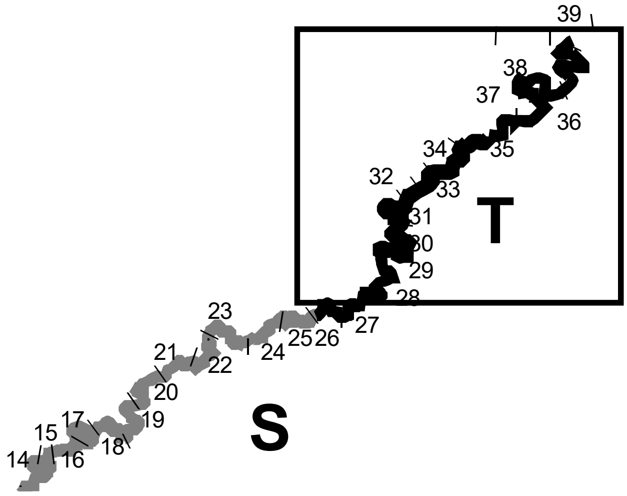
Table 16.4 Monitoring requirements for aquatic invertebrates – IFR 10

<table>
<tr><th colspan="11">BASELINE</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td rowspan="3">SASS5 survey at IFR 10 site.</td><td rowspan="3">1-5</td><td>Autumn</td><td>1</td><td></td><td>0.3</td><td rowspan="6">0.25</td><td rowspan="6"></td><td rowspan="6">0.3</td><td rowspan="6"></td></tr>
<tr><td>Winter</td><td>1</td><td></td><td>0.3</td></tr>
<tr><td>Spring</td><td>1</td><td></td><td>0.3</td></tr>
<tr><td rowspan="3">Carry out habitat assessment at IFR 10 site.</td><td rowspan="3">4+5</td><td>Autumn</td><td>1</td><td></td><td>0.1</td></tr>
<tr><td>Winter</td><td>1</td><td></td><td>0.1</td></tr>
<tr><td>Spring</td><td>1</td><td></td><td>0.1</td></tr>
</table>

17 RU T. IFR 11. MOOI RIVER FALLS (Mooi River)

17.1 SITE DESCRIPTION

The site is situated downstream of the Mooi River Falls in the gorge. The site is characterised by a large long boulder riffle. Indigenous riparian vegetation occurs on the right bank and the left bank has more terrestrial vegetation on a steep hillside.



17.2 ECOSPECS AND TPCs

Table 17.1 The various Ecospecs and related TPCs for each component – IFR 11

ECOSPECS	TPCs
Geomorphology	
1. To maintain the trajectory and relative location, composition and structure of morphological units within a reach (within a resource unit).	1.A significant change in the trajectory and relative location, composition and structure of morphological units within a reach (within a geomorphological zone).
Riparian vegetation	
1. To maintain the trajectory and relative location, extent, composition and structure of riparian and marginal vegetation on morphological units within a reach (within a resource unit)	1.A significant change in the trajectory of riparian and marginal vegetation on morphological units within a reach (within a resource unit).
Fish	
1. All 12 species expected for a B category should be present: *Labeobarbus natalensis, Labeo rubromaculatus, Amphilius natalensis, Anguilla bengalensis, Barbus anoplus etc*. (i.e. viable populations). Fish health and condition should be moderate to good.	1.Absence of any of the species.
2. All year classes of all species represented.	2. Absence or drop in abundance of any year class.
3. Maintain critical stress level below 6.8 to facilitate year round riffle habitat for *A. natalensis* and habitat and passage for *L. natalensis* and *Anguillids:* FD = 2 FS = 2 SD = 4 SS = 4. HABITAT SUITABILITY RATING: Breeding = 2 Survival/Abundance =2 Cover =3 Health = 4 Water quality =4	3. Drop in abundance of any of the flow-depth and cover classes (which would relate to increased stress).
Aquatic invertebrates	
1. To ensure that the SASS5 scores and ASPT values occur in the set range (except after major floods and during droughts). Stones biotope: SASS >130 ASPT >7.5 (in winter).	1. Stones biotope SASS5 score <120 and ASPT <7 in winter.
2. Ensure that no invertebrate taxon consistently dominates the fauna.	2. When any taxon has an abundance of >100 while all other taxa are <10, for two consecutive surveys.
3. Maintain presence of Ephemeroptera in stones biotope.	3. At least 4 Ephemeroptera families to be maintained through any two consecutive surveys.
4. Maintain suitable conditions for filter feeding organisms such as Hydropsychidae.	4. Hydropsychidae occur at abundance <10 for two consecutive surveys.
5. Flow regime to maintain the current speeds for rheophilic species.	5. Abundance of rheophilic taxa in total <100 individuals.

17.3 ANALYSIS OF LIMITATIONS IN AVAILABLE INFORMATION

17.3.1 Fish

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Information not very suitable. Proper baseline required.

Is recent information available?
No recent information is available.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding of the requirements of the target species present is generally sufficient.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Interpretive knowledge on the habitat-flow-stress response is based on *A. natalensis, L. natalensis* and Anguillids which are well known.
Twelve species expected to be present but proper baseline required to construct a FAII.

Are there suitable interpretive indices available? (SASS, H-FSR)
The flow stress habitat response provides a suitable interpretive index.

Can you discern between flow and non-flow related problems?
Flow and non-flow related problems can be distinguished.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate

17.3.2 Aquatic invertebrates

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Ten years of SASS data up until present (not divided into biotopes) is available.

Is recent information available?
Yes, although inadequate because the biotopes were joined together and analysed as one.
Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding is at a crude level – species level information and knowledge of species biology would be necessary for a better understanding.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Understanding is at a crude level – species level information and knowledge of species biology would be necessary to better understand habitat-flow-stress responses. Understanding of non-flow related issues (e.g. water quality) is better.

Are there suitable interpretive indices available? (SASS, H-FSR)
SASS is useful but does not adequately deal with flow-related issues.

Can you discern between flow and non-flow related problems?
Only to a limited extent.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate
Due to inadequate species information, the scope to interpret changes is reduced.

17.4 MONITORING REQUIREMENTS

The monitoring requirements are listed in the following tables.

Table 17.2 Monitoring requirements for fish – IFR 11

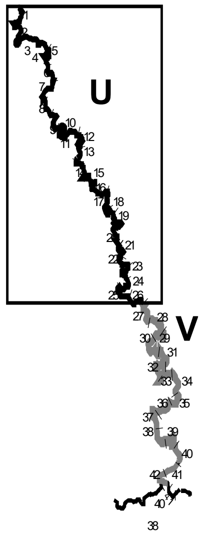
BASELINE									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
Fish survey at IFR site (and section of river reach).	1, 2, 3	Low flow season	1 Low flow season	1	1	0.5		0.5	
Seine sampling (10 efforts distributed over the section) and electro fishing (>40 minutes effort, 2 passes).									
Sampling quantified (CPUE, etc.).									
Determine length frequencies, age classes.									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).									
LONG-TERM (5YR)									
Action	**Ecospec**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
Fish survey at IFR site (and section of river reach).	1, 2, 3	Low flow season	1 Low flow season for 3 years during the baseline phase		2	0.5		0.5	
Seine sampling (and electro fishing (>40 minutes or/or 2 passes).									
Sampling quantified (CPUE, etc.).									
Determine length frequencies, age classes.									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).									

Table 17.3 Monitoring requirements for aquatic invertebrates – IFR 11

BASELINE									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
SASS5 survey at IFR 11 site.	1-5	Autumn	1		0.3	0.25		0.3	
		Winter	1		0.3				
		Spring	1		0.3				
Carry out habitat assessment at IFR 11 site.	2-5	Autumn	1		0.1				
		Winter	1		0.1				
		Spring	1		0.1				
LONG-TERM (5YR)									
Action	**Ecospec**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
SASS5 survey at IFR 11 site.	1-5	Winter	5		1.5	0.5		1.5	
Carry out habitat assessment at IFR 11 site.	2-5	Winter	5		1.5				

18 RU U. IFR 13. UPPER BUFFALO (Buffalo River)

18.1 SITE DESCRIPTION



The site is situated in RU V. The site is characterised by a mixed channel with pool/rapid morphology. The bed material consists of bedrock and boulder with sand.

18.2 ECOSPECS AND TPCs

Table 18.1 The various Ecospecs and related TPCs for each component – IFR 13

ECOSPECS	TPCs
Geomorphology	
1. To maintain the trajectory and relative location, composition and structure of morphological units within a reach (within a resource unit).	1. A significant change in the trajectory and relative location, composition and structure of morphological units within a reach (within a geomorphological zone).
Riparian vegetation	
1. To maintain the trajectory and relative location, extent, composition and structure of riparian and marginal vegetation on morphological units within a reach (within a resource unit).	1. A significant change in the trajectory of riparian and marginal vegetation on morphological units within a reach (within a resource unit).
Water quality	
1. Inorganic salts or salt ions: magnesium chloride, sodium chloride and calcium sulphate.	1. 95%ile of data must not exceed the category A upper boundary as defined by the quality ecospecs.
2. Inorganic salts or salt ions: calcium chloride.	2. 95%ile of data must not exceed the category B upper boundary as defined by the quality ecospecs.
3. Inorganic salts or salt ions: magnesium sulphate.	3. 95%ile of data must not exceed the category C upper boundary as defined by the quality ecospecs.
4. Inorganic salts or salt ions: sodium sulphate.	4. 95%ile of data must not exceed the category C upper boundary as defined by the quality ecospecs.
5. Nutrients: SRP (synonymous with PO_4 or orthophosphate).	5. 50%ile of data must not exceed the category C/D upper boundary as defined by the quality ecospecs.
6. Nutrients: TIN.	6. 50%ile of data must not exceed the category Cupper boundary as defined by the quality ecospecs.
7. System variables: pH and DO.	7. 95%ile of data must not exceed the category B upper boundary as defined by the quality ecospecs.
8. System variables: turbidity/SS.	8. A TPC cannot be provided as no data or method is currently available. Noted as developmental issue.
9. Algal abundance (chl-a).	9. Concentration must not exceed the quality ecospec for periphyton.
10. In-stream toxicity (minimum is *Daphnia*, fish and algal tests).	10. Any indication of toxicity as shown by any single test as specified in the ecospecs column (i.e. *Daphnia*, fish or algal test).
11. Toxic substances (e.g. heavy metals and ammonia)	11. Data must not exceed the CEV (DWAF, 1996).
Fish	
1. All 12 species expected for a B category should be present: *Labeobarbus natalensis, Labeo rubromaculatus, Amphilius natalensis, Anguilla bengalensis, Barbus anoplus* etc. (I.e. viable populations). Fish health and condition should be moderate to good.	1.Absence of any of the species.
2. All year classes of all species represented.	2. Absence or drop in abundance of any year class.

ECOSPECS	TPCs
3. Maintain critical stress level below 6.8 to facilitate year round riffle habitat for *A. natalensis* and habitat and passage for *L. natalensis* and *Anguillids:* FD = 2 FS = 2 SD = 4 SS = 4. HABITAT SUITABILITY RATING: Breeding = 2 Survival/Abundance =2 Cover =3 Health = 4 Water quality =4	3. Drop in abundance of any of the flow-depth and cover classes (which would relate to increased stress).
Aquatic invertebrates	
1. To ensure that the SASS5 scores and ASPT values occur in the set range (except after major floods and during droughts). Stones biotope: SASS >110 ASPT >5 (in winter).	1. Stones biotope SASS5 score <100 and ASPT <5 in winter.
2. Ensure that no invertebrate taxon consistently dominates the fauna.	2. When any taxon has an abundance of >100 while all other taxa are <10, for two consecutive surveys.
3. Maintain presence of Perlidae.	3. Absence of Perlidae for two consecutive surveys.
4. Maintain suitable conditions for filter feeding organisms such as Hydropsychidae.	4. Hydropsychidae absent for two consecutive surveys.
5. Flow regime to maintain the current speeds for rheophilic species.	5. Abundance of rheophilic taxa in total <100 individuals

18.3 ANALYSIS OF LIMITATIONS IN AVAILABLE INFORMATION

18.3.1 Water quality

Conditions to be improved as magnesium sulphate, sodium sulphate and SRP are in E/F categories. Improvements should result in a water quality EC of a C category (currently a D category).

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Yes

Is recent information available?
No

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Yes

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Yes. Nutrients (possibly resulting in elevated chl-a levels) and sulphate from mining activities.

Are there suitable interpretive indices available? (SASS, H-FSR)
No. Include chl-a, turbidity and DO.

Can you discern between flow and non-flow related problems?
Yes

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
High

18.3.2 Fish

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Information not very suitable. Proper baseline required.

Is recent information available?
No recent information is available.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding of the requirements of the target species present is generally sufficient.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Interpretive knowledge on the habitat-flow-stress response is based on *L. natalensis* and *L. rubromaculatus* which are well known.
Seven species expected to be present but proper baseline required to construct a FAII.

Are there suitable interpretive indices available? (SASS, H-FSR)
The flow stress habitat response provides a suitable interpretive index.

Can you discern between flow and non-flow related problems?
Flow and non-flow related problems can be distinguished.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate

18.3.3 Aquatic invertebrates

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Good historical data is available but the river was already impacted at that time.

Is recent information available?
Only one SASS sample.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding is limited due to lack of species information.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Understanding is limited due to lack of species information.

Are there suitable interpretive indices available? (SASS, H-FSR)
SASS is useful but does not adequately deal with flow-related issues.

Can you discern between flow and non-flow related problems?
To a limited extent as some species information exists.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate
Due to existence of historical information although the site was already impacted at that time.

18.4 MONITORING REQUIREMENTS

The monitoring requirements are listed in the following tables.

Table 18.2 Monitoring requirements for water quality – IFR 13

<table>
<tr><th colspan="11">BASELINE</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Institute (or continue) bimonthly monitoring at V3H010.</td><td>Inorganic salts, Nutrients (SRP, TIN)</td><td rowspan="4"></td><td>Bimonthly</td><td rowspan="4"></td><td rowspan="4">10 (samples collected simultaneously)</td><td rowspan="4"></td><td rowspan="4">10</td><td rowspan="4"></td><td rowspan="4">1</td></tr>
<tr><td>Add turbidity to routine sampling, and record DO during sample collection.</td><td>System variables (pH, turbidity and DO)</td><td>Bimonthly</td></tr>
<tr><td>Collect periphyton samples for chl-a analysis as no baseline exists.</td><td>Algal abundance (chl-a)</td><td>Monthly</td></tr>
<tr><td>Toxic substances (e.g. heavy metals and ammonia)</td><td></td><td>Monthly</td></tr>
<tr><th colspan="11">LONG-TERM (5YR)</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Continue bimonthly monitoring at V6H004.</td><td>Inorganic salts, nutrients (SRP, TIN)</td><td></td><td>Bimonthly</td><td rowspan="6"></td><td rowspan="5">50 (samples collected simultaneously)</td><td rowspan="6"></td><td rowspan="2">50</td><td rowspan="6">5</td><td rowspan="6"></td></tr>
<tr><td>Add turbidity to routine sampling, and record DO during sample collection.</td><td>System variables (pH, turbidity and DO)</td><td></td><td>Bimonthly</td></tr>
<tr><td>In-stream toxicity tests when poor biotic surveys not due to flow or habitat conditions.</td><td>Toxic substances</td><td></td><td>Every second month.</td><td></td></tr>
<tr><td></td><td>In-stream toxicity</td><td></td><td>React to biotic index</td><td>4 days per series of tests.</td></tr>
<tr><td>Toxic substances (e.g. heavy metals and ammonia)</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Collect periphyton samples for quarterly analysis (i.e. per season).</td><td>Algal abundance (chl-a)</td><td>S, W, A, Sp</td><td>4 (i.e. per season) / year</td><td></td><td></td></tr>
</table>

Table 18.3 Monitoring requirements for fish – IFR 13

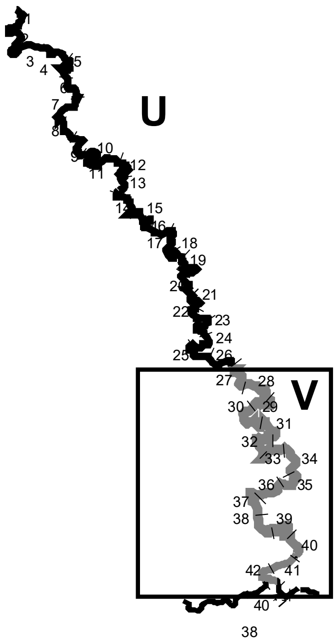
<table>
<tr><th colspan="10">BASELINE</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Fish survey at IFR site (and section of river reach).</td><td rowspan="6">1, 2, 3</td><td rowspan="6">Low flow season</td><td rowspan="6">1 Low flow season</td><td rowspan="6">1</td><td rowspan="6">1</td><td rowspan="6">0.5</td><td rowspan="6"></td><td rowspan="6">0.5</td><td rowspan="6"></td></tr>
<tr><td>Seine sampling (10 efforts distributed over the section) and electro fishing (>40 minutes effort, 2 passes).</td></tr>
<tr><td>Sampling quantified (CPUE, etc.).</td></tr>
<tr><td>Determine length frequencies, age classes.</td></tr>
<tr><td>Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.</td></tr>
<tr><td>Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).</td></tr>
<tr><th colspan="10">LONG-TERM (5YR)</th></tr>
<tr><th rowspan="3">Action</th><th rowspan="3">Ecospec/ TPC</th><th rowspan="3">Season</th><th rowspan="3">Frequency</th><th colspan="6">Human Resource (Days)</th></tr>
<tr><th colspan="2">Survey</th><th colspan="2">Analysis</th><th colspan="2">Reporting</th></tr>
<tr><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th><th>Sp</th><th>Tech</th></tr>
<tr><td>Fish survey at IFR site (and section of river reach).</td><td rowspan="6">1, 2, 3</td><td rowspan="6">Low flow season</td><td rowspan="6">1 Low flow season for 3 years during the baseline phase.</td><td rowspan="6"></td><td rowspan="6">2</td><td rowspan="6">0.5</td><td rowspan="6"></td><td rowspan="6">0.5</td><td rowspan="6"></td></tr>
<tr><td>Seine sampling (and electro fishing (>40 minutes or/or 2 passes).</td></tr>
<tr><td>Sampling quantified (CPUE, etc.).</td></tr>
<tr><td>Determine length frequencies, age classes.</td></tr>
<tr><td>Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.</td></tr>
<tr><td>Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).</td></tr>
</table>

Table 18.4 Monitoring requirements for aquatic invertebrates – IFR 13

BASELINE									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
SASS5 survey at IFR 13 site.	1-3	Autumn	1		0.3	0.25		0.3	
		Winter	1		0.3				
		Spring	1		0.3				
Carry out habitat assessment at IFR 13 site.	4+5	Autumn	1		0.1				
		Winter	1		0.1				
		Spring	1		0.1				

19 RU V. IFR 14. LOWER BUFFALO (Buffalo River)

19.1 SITE DESCRIPTION



The site is situated upstream of the confluence of the Sibindi River with the Buffalo River. The channel is mixed with pool/riffle morphology. The bed material consists of bedrock, boulder and cobble.

19.2 ECOSPECS AND TPCs

Table 19.1 The various Ecospecs and related TPCs for each component – IFR 14

ECOSPECS	TPCs
Geomorphology	
1. To maintain the trajectory and relative location, composition and structure of morphological units within a reach (within a resource unit).	1. A significant change in the trajectory and relative location, composition and structure of morphological units within a reach (within a geomorphological zone).
Riparian vegetation	
1. To maintain the trajectory and relative location, extent, composition and structure of riparian and marginal vegetation on morphological units within a reach (within a resource unit).	1. A significant change in the trajectory of riparian and marginal vegetation on morphological units within a reach (within a resource unit).
Water quality	
1. Inorganic salts or salt ions: magnesium chloride, sodium chloride and calcium sulphate.	1. 95%ile of data must not exceed the category A upper boundary as defined by the quality ecospecs.
2. Inorganic salts or salt ions: calcium chloride.	2. 95%ile of data must not exceed the category B upper boundary as defined by the quality ecospecs.
3. Inorganic salts or salt ions: magnesium sulphate.	3. 95%ile of data must not exceed the category C upper boundary as defined by the quality ecospecs.
4. Inorganic salts or salt ions: sodium sulphate.	4. 95%ile of data must not exceed the category C upper boundary as defined by the quality ecospecs.
5. Nutrients: SRP (synonymous with PO_4 or orthophosphate).	5. 50%ile of data must not exceed the category C/D upper boundary as defined by the quality ecospecs.
6. Nutrients: TIN.	6. 50%ile of data must not exceed the category Cupper boundary as defined by the quality ecospecs.
7. System variables: pH and DO.	7. 95%ile of data must not exceed the category B upper boundary as defined by the quality ecospecs.
8. System variables: turbidity/SS.	8. A TPC cannot be provided as no data or method is currently available. Noted as developmental issue.
9. Algal abundance (chl-a).	9. Concentration must not exceed the quality ecospec for periphyton.
10. In-stream toxicity (minimum is *Daphnia*, fish and algal tests).	10. Any indication of toxicity as shown by any single test as specified in the ecospecs column (i.e. *Daphnia*, fish or algal test).
11. Toxic substances (e.g. heavy metals and ammonia)	9. Concentration must not exceed the quality ecospec for periphyton.
Fish	
1. 1. All 10 species expected for a C category should be present: *Labeobarbus natalensis, Labeo rubromaculatus, Amphilius natalensis, Anguilla bengalensis, L. rubromaculatus etc*. (I.e. viable populations). Fish health and condition should be	1.Absence of any of the species.

ECOSPECS	TPCs
moderate to good.	
2. All year classes of all species represented.	2. Absence or drop in abundance of any year class.
3. Maintain critical stress level below 6.5 to facilitate year round riffle habitat for *A. natalensis* and habitat and passage for *L. natalensis* and *Anguillids:* FD = 1 FS = 3 SD = 4 SS = 3. HABITAT SUITABILITY RATING: Breeding = 2 Survival/Abundance =3 Cover =3 Health = 4 Water quality =4	3. Drop in abundance of any of the flow-depth and cover classes (which would relate to increased stress).
Aquatic invertebrates	
1. To ensure that the SASS5 scores and ASPT values occur in the set range (except after major floods and during droughts). Stones biotope: SASS >100 ASPT >6.5 (in winter).	1. Stones biotope SASS5 score <90 and ASPT <6 in winter.
2. Ensure that no invertebrate taxon consistently dominates the fauna.	2. When any taxon has an abundance of >100 while all other taxa are <10, for two consecutive surveys.
3. Maintain presence of Ephemeroptera in stones biotope.	3. At least 3 Ephemeroptera families to be maintained through any two consecutive surveys.
4. Maintain suitable conditions for filter feeding organisms such as Hydropsychidae and Simuliidae.	4. Hydropsychidae and Simuliidae occur at abundance <10 for two consecutive surveys.
5. Flow regime to maintain the current speeds for rheophilic species.	5. Abundance of rheophilic taxa in total <100 individuals.

19.3 ANALYSIS OF LIMITATIONS IN AVAILABLE INFORMATION

19.3.1 Fish

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Information not very suitable. Proper baseline required.

Is recent information available?
No recent information is available.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding of the requirements of the target species present is generally sufficient.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Interpretive knowledge on the habitat-flow-stress response is based on *A. natalensis, L. natalensis* and Anguillids which are well known.
Ten species expected to be present but proper baseline required to construct a FAII.

Are there suitable interpretive indices available? (SASS, H-FSR)
The flow stress habitat response provides a suitable interpretive index.

Can you discern between flow and non-flow related problems?
Flow and non-flow related problems can be distinguished.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Moderate

19.3.2 Aquatic invertebrates

Is sufficient information (spatial and/or temporal and/or representative) available? (If not, is there information available from comparable neighbouring catchments)
Only high level historical information available, data from the neighbouring Thukela River provides some information.

Is recent information available?
Yes, but only one SASS survey.

Is sufficient understanding (e.g. intolerances, preferences and requirements), available?
Understanding is at a crude level – species level information and knowledge of species biology would be necessary for a better understanding.

Do we understand (interpretive knowledge) the habitat-flow-stress response? (Relate to flow and non-flow related issues)
Understanding is at a crude level – species level information and knowledge of species biology would be necessary to better understand habitat-flow-stress responses. Understanding of non-flow related issues (e.g. water quality) is better.

Are there suitable interpretive indices available? (SASS, H-FSR)
SASS is useful but does not adequately deal with flow-related issues.

Can you discern between flow and non-flow related problems?
Only to a limited extent.

Based on the above questions, how high is the suitability of and confidence in the invertebrate data for interpreting biological responses to drivers?
Low / Moderate
Due to inadequate species information, the scope to interpret changes is reduced.

19.4 MONITORING REQUIREMENTS

The monitoring requirements are listed in the following tables.

Table 19.2 Monitoring requirements for fish – IFR 14

BASELINE									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
Fish survey at IFR site (and section of river reach).	1, 2, 3	Low flow season	1 Low flow season	1	1	0.5		0.5	
Seine sampling (10 efforts distributed over the section) and electro fishing (>40 minutes effort, 2 passes).									
Sampling quantified (CPUE, etc.).									
Determine length frequencies, age classes.									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).									

LONG-TERM (5YR)									
Action	**Ecospec/ TPC**	**Season**	**Frequency**	**Human Resource (Days)**					
				Survey		**Analysis**		**Reporting**	
				Sp	**Tech**	**Sp**	**Tech**	**Sp**	**Tech**
Fish survey at IFR site (and section of river reach).	1, 2, 3	Low flow season	1 Low flow season for 3 years during the baseline phase		2	0.5		0.5	
Seine sampling (and electro fishing (>40 minutes or/or 2 passes).									
Sampling quantified (CPUE, etc.).									
Determine length frequencies, age classes.									
Habitat information: basic habitat cross sections (depths and some velocities, representative photographic record), abundances of flow depth and cover classes - relate results with existing cross sectional data.									
Assess fish health/condition (externally e.g. parasites, fin condition, lesions, length-weight but time consuming).									

Table 19.3 Monitoring requirements for aquatic invertebrates – IFR 14

BASELINE									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
SASS5 survey at IFR 14 site.	1-5	Autumn	1		0.3	0.25		0.3	
		Winter	1		0.3				
		Spring	1		0.3				
Carry out habitat assessment at IFR 14 site.	4-5	Autumn	1		0.1				
		Winter	1		0.1				
		Spring	1		0.1				
LONG-TERM (5YR)									
Action	Ecospec/ TPC	Season	Frequency	Human Resource (Days)					
				Survey		Analysis		Reporting	
				Sp	Tech	Sp	Tech	Sp	Tech
SASS5 survey at IFR 14 site.	1-5					0.5		1.5	
		Winter	5		1.5				
Carry out habitat assessment at IFR 14 site.	4-5	Winter	5		1.5				

20 TOTAL COST FOR RIVER MONITORING

20.1 BASELINE MONITORING

The table below represents an integration of the individual monitoring costs for each IFR site. It does not include travel costs, disbursements and VAT. It is an estimated cost only. Cost of data management storage and management of the programme is not included.

Table 20.1 Baseline monitoring programme - BUDGET (Days)

Component	Sampling		Analysis		Reporting	
	Sp	Tech	Sp	Tech	Sp	Tech
IFR 1						
Geomorphology		4	2.5	0.5	2	0.5
Riparian vegetation	4.7		2.6	1	0.5	
Water quality		6		6	1	1
Fish	1	1	0.5		0.5	
Invertebrates		1.2	0.25		0.3	
Total	**5.7**	**12.2**	**5.85**	**7.5**	**4.3**	**1.5**
IFR 2						
Geomorphology		4	2.5	0.5	2	0.5
Riparian vegetation	4.7		2.6	1	0.5	
Water quality		6		6	1	
Fish	1	1	0.5		0.5	
Invertebrates		1.2	0.25		0.3	
Total	**5.7**	**12.2**	**5.85**	**7.5**	**4.3**	**0.5**
IFR 4						
Geomorphology		4	2.5	0.5	2	0.5
Riparian vegetation	4.7		2.6	1	0.5	
Water quality		10		10	1	
Fish	1	1	0.5		0.5	
Invertebrates		1.2	0.25		0.3	
Total	**5.7**	**16.2**	**5.85**	**11.5**	**4.3**	**0.5**
IFR 9						
Riparian vegetation	4.7		2.6	1	0.5	
Fish	1	1	0.5		0.5	
Invertebrates		1.2	0.25		0.3	
Total	**5.7**	**2.2**	**3.35**	**1**	**1.3**	
IFR 15						
Geomorphology (IFR 15 and 16)		4	2.5	0.5	2	0.5
Riparian vegetation	4.7		2.6	1	0.5	
Fish	1	1	0.5		0.5	
Invertebrates		1.2	0.25		0.3	
Total	**5.7**	**6.2**	**5.85**	**1.5**	**3.3**	**0.5**
IFR 16						
Riparian vegetation	4.7		2.6	1	0.5	
Water quality		6		12	1	
Fish	1	1	0.5		0.5	
Invertebrates		1.2	0.25		0.3	
Total	**5.7**	**8.2**	**3.35**	**13**	**2.3**	

Component	Sampling		Analysis		Reporting	
	Sp	Tech	Sp	Tech	Sp	Tech
IFR 3						
Geomorphology		4	2.5	0.5	2	0.5
Riparian vegetation	4.7		2.6	1	0.5	
Water quality		6.5		7	1.5	
Fish	1	1	0.5		0.5	
Invertebrates		1.2	0.25		0.3	
Total	**5.7**	**12.7**	**5.85**	**9.5**	**4.8**	**0.5**
IFR 5						
Geomorphology		4	2.5	0.5	2	0.5
Riparian vegetation	4.7		2.6	1	0.5	
Water quality		10		12	1	
Fish	1	1	0.5		0.5	
Invertebrates		1.2	0.25		0.3	
Total	**5.7**	**16.2**	**5.85**	**13.5**	**4.3**	**0.5**
IFR 7						
Geomorphology		4	2.5	0.5	2	0.5
Riparian vegetation	4.7		2.6	1	0.5	
Water quality		10		10	1	
Fish	1	1	0.5		0.5	
Invertebrates		1.2	0.25		0.3	
Total	**5.7**	**16.2**	**5.85**	**11.5**	**4.3**	**0.5**
IFR 8						
Riparian vegetation	4.7		2.6	1	0.5	
Fish	1	1	0.5		0.5	
Invertebrates		1.2	0.25		0.3	
Total	**5.7**	**2.2**	**3.35**	**1**	**1.3**	
IFR 10						
Geomorphology (IFR 10 and 11)		4	2.5	0.5	2	0.5
Riparian vegetation	4.7		2.6	1	0.5	
Water quality		6		6	1	
Fish	1	1	0.5		0.5	
Invertebrates		1.2	0.25		0.3	
Total	**5.7**	**12.2**	**5.85**	**7.5**	**4.3**	**0.5**
IFR 11						
Riparian vegetation	4.7		2.6	1	0.5	
Fish	1	1	0.5		0.5	
Invertebrates		1.2	0.25		0.3	
Total	**5.7**	**2.2**	**3.35**	**1**	**1.3**	
IFR 13						
Geomorphology (IFR 13 and 14)		4	2.5	0.5	2	0.5
Riparian vegetation	4.7		2.6	1	0.5	
Water quality		10		10	1	
Fish	1	1	0.5		0.5	
Invertebrates		1.2	0.25		0.3	
Total	**5.7**	**12.2**	**5.85**	**11.5**	**4.3**	**0.5**
IFR 14						
Riparian vegetation	4.7		2.6	1	0.5	
Fish	1	1	0.5		0.5	
Invertebrates		1.2	0.25		0.3	
Total	**5.7**	**2.2**	**3.35**	**1**	**1.3**	

Component	Sampling		Analysis		Reporting	
	Sp	Tech	Sp	Tech	Sp	Tech
GRAND TOTAL	**79.8**	**137.3**	**69.4**	**97.5**	**45.7**	**5.5**

20.2 LONG-TERM MONITORING

Table 20.2 Long-term monitoring programme - BUDGET (Days)

Component	Sampling		Analysis		Reporting	
	Sp	Tech	Sp	Tech	Sp	Tech
IFR 1						
Geomorphology	4		2.5	0.5	2	0.5
Riparian vegetation	4.5		2.6	1	0.5	
Water quality		40		40	4	
Fish		2	0.5		0.5	
Invertebrates		3		1.5		
Total	**8.5**	**45**	**5.6**	**43**	**7**	**0.5**
IFR 2						
Geomorphology	4		2.5	0.5	2	0.5
Riparian vegetation	4.5		2.6	1	0.5	
Water quality		30		30	4	
Fish		2	0.5		0.5	
Invertebrates		3	0.5		1.5	
Total	**8.5**	**35**	**6.1**	**31.5**	**8.5**	**0.5**
IFR 4						
Geomorphology	4		2.5	0.5	2	0.5
Riparian vegetation	4.5		2.6	1	0.5	
Water quality		50		50	4	
Fish		2	0.5		0.5	
Invertebrates		3	0.5		1.5	
Total	**8.5**	**55**	**6.1**	**51.5**	**8.5**	**0.5**
IFR 15						
Geomorphology (IFR 15 and 16)	4		2.5	0.5	2	0.5
Fish		2	0.5		0.5	
Invertebrates		3	0.5		1.5	
Total	**4**	**5**	**3.5**	**0.5**	**4**	**0.5**
IFR 16						
Riparian vegetation	4.5		2.6	1	0.5	
Water quality		40		40	4	
Total	**4.5**	**40**	**2.6**	**41**	**4.5**	
IFR 3						
Geomorphology	4		2.5	0.5	2	0.5
Riparian vegetation	4.5		2.6	1	0.5	
Water quality		42		40	4	
Fish		2	0.5		0.5	
Invertebrates		3	0.5		1.5	
Total	**8.5**	**47**	**6.1**	**41.5**	**8.5**	**0.5**
IFR 5						
Geomorphology	4		2.5	0.5	2	0.5

Component	Sampling		Analysis		Reporting	
	Sp	Tech	Sp	Tech	Sp	Tech
Riparian vegetation	4.5		2.6	1	0.5	
Water quality		30		50	6	
Fish		2	0.5		0.5	
Invertebrates		3	0.5		1.5	
Total	**8.5**	**35**	**6.1**	**51.5**	**10.5**	**0.5**
IFR 7						
Geomorphology	4		2.5	0.5	2	0.5
Riparian vegetation	4.5		2.6	1	0.5	
Water quality		40		40	4	
Fish		2	0.5		0.5	
Invertebrates		3	0.5		1.5	
Total	**8.5**	**45**	**6.1**	**41.5**	**8.5**	**0.5**
IFR 10						
Geomorphology (IFR 10 and 11)	4		2.5	0.5	2	0.5
Water quality		30		30	4	
Fish		2	0.5		0.5	
Total	**4**	**32**	**3**	**30.5**	**6.5**	**0.5**
IFR 11						
Riparian vegetation	4.5		2.6	1	0.5	
Fish		2	0.5		0.5	
Invertebrates		3	0.5		1.5	
Total	**4.5**	**5**	**3.6**	**1**	**2.5**	**0**
IFR 13						
Geomorphology (IFR 13 and 14)	4		2.5	0.5	2	0.5
Water quality		50		50	5	
Total	**4**	**50**	**2.5**	**50.5**	**7**	**0.5**
IFR 14						
Riparian vegetation	4.5		2.6	1	0.5	
Fish		2	0.5		0.5	
Invertebrates		3	0.5		1.5	
Total	**4.5**	**5**	**3.6**	**1**	**2.5**	**0**
GRAND TOTAL	**76.5**	**399**	**54.9**	**385**	**78.5**	**37.7**

21 THUKELA ESTUARY

21.1 RESERVE LEVEL

The preliminary Ecological Reserve determination for the Thukela Estuary was done at an Intermediate level. However, in the case of the Thukela Estuary sediment processes, not usually included in intermediate level studies, were also dealt with, being of particular importance in this case.

Field data on the abiotic and biotic characteristics of the Thukela Estuary in its closed state could not be collected within the time frame of this study. Therefore assessments on the behaviour of the estuary under this state are of low confidence. Monitoring activities will therefore also aim to collate more of this information.

21.2 ECOLOGICAL SPECIFICATION AND THRESHOLDS OF POTENTIAL CONCERN

Ecological Specifications are clear and measurable specifications of ecological attributes (in the case of estuaries - hydrodynamics, sediment dynamics, water quality and different biotic components) that define a specific ecological reserve category, in this case a Category C+.

Thresholds of potential concern (TPC) are defined as measurable end points related to specific abiotic or biotic indicators that if reached (or when modelling predicts that such points will be reached) prompts management action. In essence, thresholds of potential concern endpoints should be defined such that they provide early warning signals of potential non-compliance to Ecological Specifications (i.e. not the point of 'no return'). In essence, this concept implies that the indicators (or monitoring activities) selected as part of long-term monitoring programme need to include biotic and abiotic components that are particularly sensitive to ecological changes associated with changes in river inflow.

Table 21.10 shows the Ecological Specifications and associated TPCs for the different abiotic and biotic components that are required to keep the Thukela Estuary in the EC associated with Scenario 9, i.e. Category C+. This corresponds to the recommended EC of Category C+.

Table 21.1 Ecological Specifications and TPC associated with an Ecological Category C+ for the Thukela Estuary

Component	Ecological specification	Threshold of Potential Concern[1]	POTENTIAL CAUSES
Birds	Retain a species rich bird community (density and diversity) representative of Paelarctic migrant waders, water birds (cormorants, herons & egrets) and waterfowl.	1.1 Diversity and density decline to 50% of average seasonal baseline counts for two consecutive surveys focusing on waders (September -October), water birds and water fowl.	Mouth closure in spring; Invertebrate biomass/abundance; Fish biomass/abundance; Human disturbance
Fish	Retain present fish species assemblage (1997-1999).	2.1 Marine and estuarine species are > 90% of composition at all flows	Increased proportion of Mozambique tilapia (*Oreochromis mossambicus*)
	Maintain fish migrations of catadromous species to freshwater habitats, e.g. eels	2.2 Sampling at head of estuary between September and January reveal no presence of eel larvae	Blockage of eel migrations due to sand bar at mouth, Bad catchment practises/destruction of habitat, Blockage of migration due to dams.
	Maintain juvenile fish immigration to estuary	2.3 Reduced numbers of juvenile marine cohorts in spring compared to baseline data set (1997-1999)	Mouth closure during late winter spring
	Prevention of any fish kill	2.4 Any fish kill recorded	Water quality pollution etc.
Invertebrates	*Benthic Invertebrates:*		
	Maintain current levels of zoobenthic abundance (including seasonal variation)	3.1 Decrease in abundance of >25% in terms of numbers/ m^{-2} over entire estuarine area (6 sample sites)	Changes to sediment grain size distribution and organic content
	During November to April when flows are >30 m^3/s (high flows), zoobenthic invertebrates dominated by Insecta and Acariformes	3.2 Loss of two groups of either Ephemeroptera, Odonata, Hemiptera, Diptera, Trichoptera or Hydracarina	Organic loading of sediments or other water quality changes resulting in deoxygenation of the sediment/water interface
	During May - October, when flows are between 5-30 m^3/s zoobenthic invertebrates must be characterised by predominantly estuarine taxa	3.3 <50% of benthic invertebrates (by abundance) are typically estuarine taxa	Mouth condition (recruitment of larvae)
	Retain current species richness of Polychaeta, Crustacea and Mollusca during May - October when flows are normally between 5-30 m^3/s	3.4 Loss of 50% of polychaete and crustacean species excluding *Desdemona ornata* and 40% of molluscs species present during winter	Salinity gradient; Mouth closure
	Maintain species of regionally endemic Polychaeta during May - October when flows are normally between 5-30 m^3/s	3.5 *Desdemona ornata* contribution to benthic abundance declines to 70%	Salinity gradient; Mouth closure
	Taxa indicative of 'stressed' conditions, i.e. water quality should not dominate benthic abundance	3.6 *Prionospio sexoculata*, *Capitella capitata*, *Chironomidae* or *Oligochaeta* contribute >50% of abundance at any sample site during any season	Salinity gradient; Mouth closure
	Macrocrustacea:		
	Ensure that the catadromous crab, *Varuna litterata* has access to and from the estuary during emigration and immigration	*3.7* *Varuna* adults absent from the estuary during late summer (Jan - Feb). *Varuna megalopae* absent from the estuary during late autumn/early winter (April-June) surveys for two consecutive surveys	Salinity gradient
	Ensure catadromous caridean prawns (*Macrobrachium*) have access to spawning areas in the estuary	3.8 Loss of two species of *Macrobrachium* (other than *M. rude*) over consecutive surveys during summer	Loss of marginal vegetation
	Zooplankton:		
	Maintain estuarine zooplankton community in terms of abundance and diversity	3.9 >25% loss in current diversity and abundance over two consecutive surveys (taking into account time of year)	Water quality and depth

Table 21.2 Continued…

Component	Ecological specification	Threshold of Potential Concern[1]	POTENTIAL CAUSES
Macrophytes	Maintain the present distribution (2001) and abundance of the different plant community types. Reeds e.g. *Phragmites australis* (~20ha), sedges e.g. *Schoenoplectus scirpoideus* (~20ha)	4.1 Greater than 20% change in the area covered by different plant community types	Increase in closed mouth condition and changes in water level and salinity.
	Control the spread of invasive alien plants e.g. Brazilian Pepper tree in wetland areas	4.2 Greater than 20% decrease in wetland area as a result of alien vegetation encroachment	Suitable habitat e.g. saline conditions, disturbed soils and habitats that are created by drainage and farming activities
	Control the spread of reeds into the main channel	4.3 Greater than 20 % increase in reed growth in the main channel at the expense of open water area.	Sedimentation and stable sediment environment
	Prevent the spread of macrophytes e.g. bulrush and water hyacinth associated with eutrophic conditions	4.4 Establishment of, for example water hyacinth during low flow conditions.	Increase in nutrients and low flow conditions (<5.0 m^3/s)
Microalgae	Maintain phytoplankton biomass in upper reaches as under baseline conditions	5.1 Phytoplankton outside range 10-150 µg/L in upper reaches of the estuary at low flow.	Extended mouth closure and anoxia. Changes in water quality e.g. increase in turbidity and nutrients.
	Maintain phytoplankton group diversity (diatoms, dinoflagellates, flagellates, greens etc.).	5.2 Dominance (> 10% relative abundance) of one bloom-forming group of algae (i.e. blue-greens, diatoms & dinoflagellates).	Extended mouth closure and anoxia. Changes in water quality e.g. increase in turbidity and nutrients.
	Maintain intertidal and subtidal biomass of benthic microalgae in sheltered shallow waters	5.3 Benthic microalgal biomass decrease below 6mg/g and 3mg/g in intertidal & subtidal sediments, respectively.	Disturbance of sediments; Changes in water quality e.g. increase in turbidity and nutrients; Changes in flow.
	Maintain benthic microalgal species diversity (i.e. blue-greens, greens, diatoms & euglenoids).	5.4 Less than 10 taxa for any sampling session	Disturbance of sediments; Changes in water quality e.g. increase in turbidity and nutrients; Changes in flow.
Water quality	Salinity intrusion should not cause exceedence of TPCs for fish, invertebrates, macrophytes and microalgae (see above)	6.1 Salinity during low flows is >10 ppt, 4 km upstream of the mouth for longer than 4 months.	Modification of inflow at head of estuary
	System variables (pH, turbidity, dissolved oxygen, suspended solids and turbidity) not to cause exceedence of TPCs for biota (see above)	6.2 pH > 8.5 or < 6.5 in river inflow or in estuary	Quality of river inflow at head of estuary, e.g. affected by catchment activities and wastewater discharges at Mandini Industrial area
		6.3 Turbidity in river inflow outside the range. - ……NTU (except during floods) (no reliable data - to be determined after baseline study)	
		6.4 Suspended sediment concentrations at Mandini flow gauge not within 95% of the discharge sediment load relationship as determine for the baseline study	Modification to inflow at head of estuary; Catchment activities
		6.5 SS in river inflow outside range. - ….. mg/L (except during floods) (no reliable data - to be determined after baseline study)	Quality of river inflow at head of estuary, e.g. affected by catchment activities and organic inputs from wastewater discharges at Mandini Industrial Area
		6.6 Organic content in sediments not within 95% of the organic load as determine for the baseline study	
		6.7 Dissolved oxygen concentrations in river inflow and in estuary fall below 6 mg/L.	
	Inorganic nutrient concentrations not to cause exceedence of TPCs for macrophytes and microalgae (see above).	6.8 Inorganic nitrogen (DIN) concentrations (limiting nutrient in marine/estuarine systems) > 0.5 mg/litre in river inflow for 2 consecutive surveys. DIN > 1 mg/L in any survey	Quality of river inflow at head of estuary, e.g. affected by catchment activities and wastewater discharges (sewage) from Mandini
		6.9 Reactive phosphate (SRP) >0.058 mg/L in river inflow for 2 consecutive surveys. SRP > 1 mg/L in any survey	
	Presence of toxic substances not to cause exceedence of TPCs for biota (see above).	6.10 Trace metals accumulation in sediments exceeds baseline data (as measured in August 2001). For pesticides/herbicides baseline studies still need to be undertaken before TPCs can be set.	Quality of river inflow at head of estuary, e.g. affected by catchment activities and wastewater discharges (sewage) from Mandini

Table 21.3 Continued…

Component	Ecological specification	Threshold of Potential Concern	POTENTIAL CAUSES
Hydrodynamics	Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality	7.1 River inflow distribution patterns differ by more than 5% from that of Scenario 9 (i.e. selected flow scenario for the Thukela)	Modification to inflow at head of estuary
	Maintain the distribution of open and closed mouth status to allow for habitat requirements and migratory functions of birds, fish, macrophytes, microalgae and water quality.	7.2 Mouth not permanently open mouth during November – April; Closed mouth conditions for longer than 1 month during May to October.	Modification to inflow at head of estuary
Sediment dynamics	Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota (see above)	8.1 River inflow distribution patterns (flood components) differ by more than 5% from that of Scenario 9 (i.e. selected flow scenario for the Thukela)	Modification to inflow at head of estuary
	Changes in sediment grain size distribution patterns not to cause exceedence of TPCs in benthic invertebrates (see above).	8.2 The median bed sediment diameter deviate by more than factor 3 as recorded in the baseline study.	Modification to inflow at head of estuary; Catchment activities

[1] All TPCs stated as percentages relates to the percentage deviation from reference Condition.

21.3 BASELINE DATA REQUIREMENTS (INCLUDING HUMAN RESOURCES)

This section lists the additional data that are still required to provide a suitable and reliable baseline for the different abiotic and biotic components in a long-term monitoring programme.

The approach followed for estuaries was to assume that the baseline data requirements stipulated for a Comprehensive Ecological Reserve Determination in the Estuaries RDM Methodology as the suitable baseline data set. The status of baseline data for different abiotic and biotic components in the Thukela Estuary is discussed in greater detail below.

21.3.1 Abiotic components

i. Sediment dynamics

Suitable Baseline data	Outstanding (I.e. proposed action required)	Motivation
Series of cross-section profiles collected at fixed 500 m, but more detailed in the mouth (0.5 m intervals at 1:2000 scale or better)	Recent profiles to set the baseline for both the closed and open states (previous records are about 5 years old and are only available for the open state).	To set the baseline conditions to monitoring sediment deposition rate in estuary.
Series of sediment core samples for the analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations) taken every 3 years along the length of an estuary (200 m to 2 km intervals)	None (cores were taken in 2001)	The cores that were taken showed a uniform sediment distribution.
Set of cross-section profiles and a set of sediment grab samples for analysis of particle size distribution (PSD) and origin (i.e. using microscopic observations), need to be taken immediately after a major flood	Recent sections required to set baseline (previous records about 5 years old)	System is very dynamics and it would have changed over the past years. To be able to interpret invertebrate data, particle size distribution must be collected at the same time as the invertebrate data sets (if not, measurements will have to be repeated at invertebrate stations when those studies are conducted)
Velocity cross section data during a neap and spring tide at 200 m upstream of the mouth taken in the same period as the cross section profiles	Velocity cross section data required	Required to for quantify non-uniformity across the width of the estuary in terms of stream power and sediment dynamics
Daily sampling of suspended sediment (maybe also organic) matter at the Mandini gauging weir with turbidity meter to be calibrated (larger than 2000 NTU)	Daily sampling of suspended sediment matter (previous data were collected in 1971-1981)	Required to quantify actual sediment yield and variability entering the estuary from the catchment.

ii. Hydrodynamics

Suitable Baseline data	Outstanding (I.e. proposed action required)	Motivation
Measured river inflow data (gauging station) at the head of the estuary	Gauging station at Mandini is operational. Flows of waste water discharges, (e.g. Sappi Mandini) downstream of this point must also be measured continuously (this is in any way a legal requirement under the National Water Act)	Crucial primary baseline data set for estuarine reserve determination. Also required to re-calibrate the simulated flow data because there are discrepancies between measured and simulated data at present.
Aerial photographs of estuary (earliest available year as well as most recent)	Recent photo at low spring tide	To set baseline for development in flood plain and position of mouth. If taken at low spring tide it can also be used to characterize baseline conditions of intertidal area and flood plain in terms vegetation cover and physical habitat for fauna.
Nearshore wave data records (only if available)	None	-
Daily mouth observations	Programme to record mouth status on a daily basis in the low flow period.	Crucial baseline data set need to record the state of the mouth
Continuous water level recordings near mouth of the estuary	A DWAF continuous water level recorder is already installed (~2.5 km upstream on the north bank), but must be maintained	Crucial baseline data set recording the state of the mouth and sedimentation
Water level recordings at about 5 locations along the length of the	Water level recordings over a 2-week period over a neap and spring tidal cycles	To be able to quantify the bed roughness

Suitable Baseline data	Outstanding (I.e. proposed action required)	Motivation
estuary over a spring and a neap tidal cycle (i.e. at least a 14 day period).		

iii. Water Quality

Suitable Baseline data	Outstanding (I.e. proposed action required)	Motivation
Longitudinal salinity and temperature profiles (in situ) collected over a spring and neap tide during high and low tide at: • end of low flow season (i.e. period of maximum seawater intrusion) • peak of high flow season (i.e. period of maximum flushing by river water)	Closed state measurements	Salinity distribution in the estuary may change substantially during a closed state To be able to interpret biotic data, salinity and temperature data must be collected at the same time as the fish, invertebrate, macrophyte and microalgae data sets (if not, measurements will have to be repeated at biotic stations when those studies are conducted)
Water quality measurements (i.e. system variables, and nutrients) taken along the length of the estuary (surface and bottom samples) on a spring and neap high tide at: • end of low flow season • peak of high flow season	Closed state measurements including pH, dissolved oxygen, suspended solids, turbidity, inorganic nutrients, organic carbon and nitrogen.	Water quality in the estuary may change substantially during a closed state and needs to be recorded to be able to interpret biological data To be able to interpret biotic data, data on system variables must be collected at the same time as the fish, invertebrate and microalgae data sets, while inorganic nutrient data must also be collected at the same time as the microalgae data sets (if not, measurements will have to be repeated at biotic stations when those studies are conducted)
Water quality (e.g. system variables, nutrients and toxic substances) measurements on river water entering at the head of the estuary	Reliable record on seasonal variability in quality of river inflow at the N2 bridge (if not at old bridge) for conductivity, temperature, suspended matter (e.g. reflecting lignin inputs), turbidity, dissolved oxygen, pH, inorganic nutrients, possibly also organic carbon/ nitrogen input. To set baseline conditions at least a 5-year record of monthly sampling is required.	This is important boundary condition for all components
Water quality (e.g. system variables, nutrients and toxic) substances) measurements of nearshore seawater	No additional measurements required - consult available literature on marine water quality in the area	-
Measurements of organic content and toxic substances in sediments along length of the estuary (particularly depositional areas)	None for trace metal (August 2001 survey can be used as baseline data). May still require baseline data set for pesticides/herbicides. Organic content required for invertebrate baseline surveys during closed phase.	Agricultural activities in the catchment may have resulted in the accumulation of pesticides/herbicides in the estuary, however, this need to be confirmed with a baseline survey. To be able to interpret invertebrate data, organic content data must be collected at the same time as the invertebrate data sets.

21.3.2 Biotic Components

i. Microalgae

Suitable Baseline data	Outstanding (I.e. proposed action required)	Motivation
Chlorophyll-a measurements taken at 5 stations (at least) at the surface, 0.5 m and 1 m depths thereafter. Cell counts of dominant phytoplankton groups i.e. flagellates, dinoflagellates, diatoms and blue-green algae. Measurements should be taken coinciding with typically high and low	Closed mouth condition to be sampled	Changes in water quality expected during this state may result in changes in community composition, e.g. nuisance algae. High flow was not measured, but it was not considered important in this system, i.e. there will be nothing due to strong flows

Suitable Baseline data	Outstanding (I.e. proposed action required)	Motivation
flow conditions.		
Intertidal and subtidal benthic chlorophyll-a measurements taken at 5 stations. Epipelic diatoms need to be collected for identification. Measurements should be taken coinciding with a typical high and low flow condition (in temporarily closed estuaries measurements must include open as well as closed mouth conditions).	Closed mouth condition to be sampled	Changes in water quality expected during this state may result in changes in community composition, e.g. nuisance algae. High flow was not measured, but it was not considered important in this system, i.e. there will be nothing due to the strong flows Loss of intertidal habitat may change benthic microalgal biomass

ii. Macrophytes

Suitable Baseline data	Outstanding (I.e. proposed action required)	Motivation
Aerial photographs of the estuary (ideally 1:5000 scale) reflecting the present state, as well as the reference condition (if available) Available orthophoto maps	None	Baseline GIS map (2001) is available.
Number of plant community types, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit.	None	This has been documented during the baseline study (2001).
Permanent transects (a fixed monitoring station that can be used to measure change in vegetation in response to changes in salinity and inundation patterns)[2]: Measurements of percentage plant cover along an elevation gradient Measurements of salinity, water level, sediment moisture content and turbidity	None	Not considered relevant for the Thukela as there are no salt marsh areas.

iii. Invertebrates

Suitable Baseline data	Outstanding (I.e. proposed action required)	Motivation
Compile a detailed sediment distribution map of the estuary. Obtain a detailed determination of the extent and distribution of shallows and tidally exposed substrates.	No overall sediment map has been compiled to be able to extrapolate/predict situation for entire system for the closed state.	During the closed state and extreme low flows, deposition of fine sediments may occur and this could prevent typically estuarine species from colonizing the estuary. To improve predictive management decision-making.
Collect a set of six benthic samples each consisting of five grabs. Collect two each from sand, mud and interface substrates. If possible, spread sites for each between upper and lower reaches of the estuary. One mud sample should be in an organically rich area. Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at spring tides.	**Sampling survey for a closed mouth state**	Expect the community may change markedly during the closed state.
Collect two sets of beam trawl samples (i.e. over mud and sand). Lay two sets of five, baited prawn/crab traps overnight, one each in the upper and lower reaches of the estuary. Species should be identified to the lowest taxon	Seasonal sampling survey including a closed mouth state (for Macrobrachium and penaeids)	Need to characterise seasonal variability and conditions for mouth closure. In particular to refine data on seasonal requirements in terms of salinity.

Suitable Baseline data	Outstanding (I.e. proposed action required)	Motivation
possible and densities (animal/m^2) must also be determined. Survey as much shoreline as possible for signs of crabs and prawns and record observations. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at spring tides.		
Collect three zooplankton samples, at night, one each from the upper, middle and lower reaches of the estuary. Seasonal (i.e. quarterly) data sets for at least one year are required, preferably collected at spring tides.	Seasonal sampling survey including a closed mouth state	Zooplankton is not considered to be an important biotic component for the Thukela.
Additional trip(s) may be required to gather data on the occurrence/ recruitment and emigration of key species such as *Varuna litterata* and *Upogebia* which require a connection to the marine environment at specific times of the year.	Surveys to track movement of Varuna over the new moon (Apr, May & Jun). Establish extent of distribution of adults (in summer) and megalopae (immediately post recruitment into the estuary) as far up as IFR site 15.	This is a crucial determinant for refinement of flow requirements during those months.
Additional trip(s) may be required to gather data on occurrence/recruitment and emigration of key which require a connection to estuarine environment at specific times of the year.	Surveys to track movement of Machrobrachium spp. during October, December & February to determine when they come down from the river into the estuary. Establish extent of distribution of adults and juveniles throughout the catchment (rivers component).	This is a crucial determinant for refinement of flow requirements during those months.

iv. Fish

Suitable Baseline data	Outstanding (I.e. proposed action required)	Motivation
In a small estuary (<5km) collect at minimum three sets of samples from the lower, middle and upper reaches of the estuary. The samples should be representative of the different estuarine habitat types, e.g. Zostera beds, prawn beds, sand flats. At least one of the sample sets need to be in the 0 to 10 ppt reach of the estuary. Sampling should be representative of small fish (seine nets) and large fish (gill nets). Sampling should be done in all four seasons for the full extent of the system (as far as tidal variation) to allow for predictive capabilities.	Effect of mouth closure on fish community NOTE: Gill nets are inappropriate for sampling of Thukela (flows too high). Seine netting was the ideal method to sample this particular system	Expect the fish community may change markedly during the closed state.

v. Birds

Suitable Baseline data	Outstanding (I.e. proposed action required)	Motivation
Undertake one full count of all water associated birds, covering as much of the estuarine area as possible. All birds should be identified to species level and the total number of each counted. Monthly data sets for at least one year are required. If this is not possible, a minimum of four summer months and one winter month will be required (decisions on the extent of effort required will depend largely on the size of the estuary, extent of shallows present, as well as extent of tidally exposed areas).	Effect of mouth closure on bird populations.	Increased depth and loss of intertidal areas affecting feeding and roosting.

Taking the above into account, specific actions and associated human resources to obtain such data are listed in Table 21.11.

These have been prioritised, using colour coding, as follows:

(blue)	(green)	High priority, considered as a minimum requirement for a suitable baseline data set (blue indicates data sets linked to the closed state, a condition that was supposed to be sampled as part of the Intermediate RDM study, but which has not occurred as the mouth did not close during the programme)
(orange)		Medium Priority, will improve the confidence of the baseline, and should be added if funding is available
(red)		Low priority, will further improve the confidence of the baseline, but not considered to be a critical factor in the case of the Thukela Estuary

Table 21.4 Additional data requirements to set a baseline for long-term monitoring in the Thukela Estuary

Ecological component	Monitoring action	Related TPC	Temporal scale (frequency and when)	Spatial scale (No. Stations)	Human Resources (as days/year)					
					Sampling		Analysis		Reporting	
					Scientist	Tech	Scientist	Tech	Scientist	Tech
BIRDS	Full count of all water associated birds, identified to species level and the total number of each counted.	1.1	Once, 2 wks after closure	Entire estuary	1 x 1	-	-	-	1 x 1	-
	Evaluate available baseline data set against CWAC counts to determine the appropriateness of using CWAC for long-term monitoring	1.1	Once	Entire estuary	-	-	-	-	1 x 1	-
FISH	Collect fish data using seine nets	2.1 & 2.3	Once, 2 wks and 6 wks after closure	10 stns form lower, middle and upper reaches of estuary	1 x 2	1 x 2	1 x 1	1 x 2	1 x 3	-
	Nocturnal sampling of eel larvae at head of estuary using scoop nets (incorporate information from IFR stations)	2.2	Five surveys between Sept and Jan	Head of estuary	1 x 1	2 x 5	-	1 x 5	1 x 3	-
INVERTEBRATES	During mouth closure collect benthic invertebrates using Zabalocki-type Eckman grab (5 replicates/stn)	3.1 – 3.6	Once, 2 wks and 6 wks after closure	6 stns, from upper middle and lower reaches	-	2 x 2	1 x 10	1 x 3	1 x 5	-
	Collect beam trawl samples (i.e. over mud and sand) - 2 replicates/stn. Set baited prawn/crab traps overnight (5 replicates/stn). Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined.	3.7 & 3.8	Once seasonally Once, 2 wks and 6 wks after closure	Trawls 3 stns Traps 2 stns (upper and lower reaches)		2 x 4 2 x 2	1 x 4 1 x 3	1 x 2 1 x 2	1 x 3 1 x 2	-
	Sample for the occurrence of *Varuna* adults and megalopae in the lower catchment (including observations from all IFR sites)	3.7	Once during June/July (megalopae) and Nov - Feb (adults)	As required along length of estuary/river	1 x 3	1 x 3	-	1 x 2	1 x 2	-
	Set baited prawn traps overnight to collect samples of *Macrobrachium* (5 replicates/stn).	3.8	Once during October, December & February	2 stns (upper and lower reaches)		2 x 3	-	2 x 3	1 x 2	
	Collect samples over new moon (Apr, May & Jun) to find out when *Varuna* megalopae enter the system (use zooplankton WP2 trawl every 1.5 hours from dusk till dawn)	3.7	Once during April, May & June	At the mouth		2 x 3	-	2 x 3	1 x 4	-
	Collect samples over the full moon (Jan, Feb & March) to find out when *Varuna* adults leave the system using small seine nets.	3.7	Once, continuous for a day in Jan, Feb & March	Throughout estuary		2 x 3	-	1 x 3	1 x 1	-

Table 21.5 Continued…

Ecological component	Monitoring action	Related TPC	Temporal scale (frequency and when)	Spatial scale (No. Stations)	Human Resources (as days/year)					
					Sampling		Analysis		Scientist Tech	
					Scientist	Tech	Scientist	Tech	Scientist	Tech
	Collect zooplankton samples, at night, (2 replicates/stn)	3.9	Once, 2 wks and 6 wks after closure	3 stns, from upper, middle and lower reaches of estuary	-	2 x 2	1 x 2	1 x 1	1 x 2	-
MACROPHYTES	None required	-	-	-	-	-	-	-	-	-
MICROALGAE	Measure phytoplankton biomass and group composition for a closed phase.	5.1 – 5.2	Once, 2 wks and 6 wks after closure	6 stns	1 x 2	1 x 2	2 x 2	3 x 2	1 x 4	-
	Measure benthic microalgal biomass and species composition for a closed phase.	5.3 – 5.4	Once, 2 wks and 6 wks after closure	6 stns	1 x 2	1 x 2	2 x 2	3 x 2	1 x 4	-
WATER QUALITY	Collect bi-monthly data on conductivity, temperature, suspended matter (e.g. reflecting lignin inputs), turbidity/light penetration, dissolved oxygen, pH, inorganic nutrients and organic content	6.2 – 6.9	Bi monthly	At N2 bridge or best accessible location further downstream	Recommend that station be included in the DWAF's water quality monitoring programme on the Thukela Estuary (see also data requirements for Rivers – IFR 16)					
	Longitudinal salinity and temperature profiles (in situ) collected during the closed state	6.1	Once, 2 wks and 6 wks after closure	6 stns	1 x 2	1 x 2	*In situ* measurements		1 x 1	-
	Water quality measurements taken along the length of the estuary (surface and bottom samples) for pH, dissolved oxygen, suspended solids, turbidity (i.e. system variables) & inorganic nutrients.	6.2 – 6.9	Once, 2 wks and 6 wks after closure	6 stns			*In situ* measurements otherwise accredited analytical laboratory		1 x 1	-
	Measurements of pesticides/herbicides in sediments along length of the estuary	6.10	Once	3-6 stns			Accredited analytical laboratory		1 x 1	-
HYDRODYNAMICS	Water level recordings	7.1 – 7.2	Continuous	Near mouth	Included in DWAF national monitoring programme				1 x 1	-
	Flow gauging	7.1 – 7.2	Continuous	Mandini gauging stn (plus additional downstream inflow)	Included in DWAF national monitoring programme				1 x 1	-
	Mouth observations in the low flow period by local residents	7.1 – 7.2	Daily	At mouth	-	-	-	-	1 x1	-
	Aerial photographs of estuary (earliest available year as well as most recent)	7.1 – 7.2	Once	Entire estuary	To be recommended for inclusion in the DEAT national coastal survey programme				1 x 1	-
	Water level recordings along the length of the estuary (done at the same time as cross section profile survey)	7.1 – 7.2 8.1 – 8.2	Spring & neap tidal cycles (2 wks each)	3 stns	-	1 x 2	-	1 x 1	-	1 x 1
	Velocity recordings over a spring & a neap tidal cycle (done at the same time as cross section profile survey)	8.1 – 8.2	Over a spring and a neap tidal cycle	200 m upstream of mouth	-	3 x 4	-	1 x 3	1 x 1	-

Table 21.6 Continued…

Ecological component	Monitoring action	Related TPC	Temporal scale (frequency and when)	Spatial scale (No. Stations)	Human Resources (as days/year)					
					Sampling		Analysis		Scientist Tech	
					Scientist	Tech	Scientist	Tech	Scientist	Tech
SEDIMENT DYNAMICS	Series of cross-section profiles	8.1 -8.2	Once	500 m intervals but with 0.5 m intervals at 1:2000 scale or better in mouth area	-	3 x 2	-	1 x 1	1 x1	-
	Sediment core samples for detailed particle size distribution (PSD) and origin (i.e. using microscopic observations)	8.1 -8.2	Once	10 stns along entire estuary	-	1 x 1	-	R8000/ survey	1 x1	-
	Additional sediment grab samples for analysis of particle size distribution (PSD)	8.1 -8.2	Once, coinciding with invertebrate sampling	33 stns	-	1 x 1	-	R5000/survey	1 x1	-
	Daily sampling of suspended sediment (maybe also organic) matter at the Mandini gauging weir with turbidity meter to be calibrated (larger than 2000 NTU). Included in DWAF monitoring programme	8.1 – 8.2	Daily for 5 years	Mandini gauging stn	1 x 1	1 x 12	1 x 1	R24000/per year	1 x 1	-

21.4 LONG-TERM MONITORING PROGRAMME

21.4.1 Data Requirements and Human Resources

The purpose of long-term monitoring programmes, in this context, is to assess (or audit) whether the Ecological Specifications (defined as part of the Ecological Reserve determination process) are being complied with after implementation of the Reserve. In addition, these programmes can also be used to improve and refine the Ecological Reserve measures (including the Ecological Specifications), in the longer-term through an iterative process (Taljaard *et al.*, 2003)

Although baseline studies 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 derived from the monitoring activities conducted as part of the baseline studies, but implemented on less intensive spatial and/or temporal scales (Taljaard *et al.*, 2003).

Abiotic and biotic indicators considered relevant for a long-term monitoring programme on the Thukela Estuary is listed in Table 21.12. Similar to the baseline data requirements these have been prioritised, using colour coding, as follows:

(green)	High priority, considered as a minimum list of indicators to sufficiently monitor the effectiveness of the Reserve
(orange)	Medium Priority, will improve the confidence of the auditing process and should be added to the process if funding is available
(red)	Low priority, will add to the overall confidence of the auditing process, but not considered to be a critical indicator in the case of the Thukela Estuary

Table 21.7 Long-term monitoring programme proposed for the Thukela Estuary after implementation of the Reserve

Ecological component	Monitoring action	Related TPC	Temporal scale (frequency and when)	Spatial scale (No. Stations)	Human Resources (as days/year)					
					Sampling		Analysis		Reporting	
					Scientist	Tech	Scientist	Tech	Scientist	Tech
BIRDS	Full count of all water associated birds, identified to species level and the total number of each counted.	1.1	2 years after implementation thereafter every 3 years in Sept/Oct	Entire estuary	1 x 1	-	-	-	1 x 1	-
	(through CWAC counts)		Use data from CWAC surveys		-	-	-	-	1 x 2	-
FISH	Collect fish data using seine nets	2.1 & 2.3	2 years after implementation thereafter every 3 years in Sept/Oct	10 stns	1 x 2	1 x 2	1 x 1	1 x 2	1 x 3	-
	When there is a fish kill collect samples as required	2.4	Immediately after fish kill, followed by a survey 1-2 months after event	As required	1 x 1	1 x 2 1 x 1 (for 2nd survey)	-	1 x 2	1 x 1	-
INVERTEBRATES	Collect benthic invertebrates using Zabalocki-type Eckman grab (5 replicates/stn)	3.1 – 3.6	2 surveys per sampling year: Sept/Oct (low flow) & February (high flow)	6 stns	-	2 x 2	1 x 10	1 x 3	1 x 5	-
	Collect beam trawl samples (i.e. over mud and sand) - 2 replicates/stn. Set baited prawn/crab traps overnight (5 replicates/stn). Species should be identified to the lowest taxon possible and densities (animal/m^2) must also be determined.	3.7 & 3.8	2 surveys per sampling year: Sept/Oct (low flow) & February (high flow)	Trawls 3 stns Traps 2 stns (upper and lower reaches)	-	2 x 2	1 x 3	1 x 2	1 x 2	-
	Collect samples over new moon (Apr, May & Jun) to find out when *Varuna* megalopae enter the system (use zooplankton WP2 trawl every 1.5 hours from dusk till dawn) - ONLY if *Varuna* are absent from IFR sites where these were identified under the baseline study	3.7	3 surveys per sampling year: April, May & June	At mouth		(2 x 3)	-	(2 x 3)	(1 x 2)	-
	Sample over the full moon (Jan, Feb or March) to find out when *Varuna* adults leave the system using small seine nets	3.7	3 surveys per sampling year: Continuous for a day in Jan, Feb &r March	Throughout estuary	-	2 x 3	-	1 x 2	1 x 2	-

Table 21.8 Continued…

Ecological component	Monitoring action	Related TPC	Temporal scale (frequency and when)	Spatial scale (No. Stations)	Human Resources (as days/year)					
					Sampling		Analysis		Reporting	
	Set baited prawn traps overnight to collect samples of *Macrobrachium* (5 replicates/stn).	3.8	3 surveys per sampling year: October, December & February	2 stns (upper and lower reaches)	-	2 x 3	-	2 x 3	1 x 2	-
	Collect zooplankton samples, at night, (2 replicates/stn)	3.9	Once, 2 wks and 6 wks after closure	3 stns, from upper, middle and lower reaches of estuary	-	2 x 2	1 x 2	1 x 1	1 x 2	-
MACROPHYTES	Use aerial photographs to quantify area covered by different plant community types. Conduct ground survey to: 1) verify areas covered by different plant community types, 2) check the spread of alien vegetation, 3) check the spread of reeds into the main channel, 4) check for presence of aquatic weeds e.g. water hyacinth. Produce a GIS map for comparison with baseline.	4.1 -4.4	2 years after implementation thereafter every 3 years in Sept/Oct	Entire estuary	1 x 1	1 x 1	1 x 2	1 x 3	1 x 1	1 x 1
MICROALGAE	Measure phytoplankton biomass (Chl a) during low flow. ONLY if TPC is exceeded then initiate group and species identification studies	5.1 – 5.2	2 years after implementation thereafter every 3 years in Sept/Oct (flow <10 m^3/s)	6 stns	1 x 1	1 x 1	1 x 2	1 x 3	1 x 4	-
	Measure phytoplankton biomass (Chl a) during low flow. ONLY if TPC is exceeded then initiate group and species identification studies	5.3 – 5.4	2 years after implementation thereafter every 3 years in Sept/Oct (flow <10 m^3/s)	6 stns	1 x 1	1 x 1	1 x 2	1 x 3	1 x 4	-
	When there is an algal bloom collect samples as required	5.1 – 5.2	Immediately and at 2 wks intervals for 6 wks	6 stns	1 x 3	1 x 3	2 x 3	2 x 3	1 x 4	-
WATER QUALITY	Continue bi-monthly data collection on conductivity, temperature, suspended matter (e.g. reflecting lignin inputs), turbidity/light penetration, dissolved oxygen, pH, inorganic nutrients and organic content	6.2 – 6.9	Bi monthly	At N2 bridge or best accessible location further downstream	Recommend that station be included in the DWAF's water quality monitoring programme on the Thukela Estuary (see also data requirements for Rivers – IFR 16)					

Table 21.9 Continued…

Ecological component	Monitoring action	Related TPC	Temporal scale (frequency and when)	Spatial scale (No. Stations)	Human Resources (as days/year)					
					Sampling		Analysis		Reporting	
					Scientist	Tech	Scientist	Tech	Scientist	Tech
	Dedicated longitudinal salinity and temperature profiles (also required for interpretation of biotic data)	6.1	2 years after implementation thereafter every 3 years in Sept/Oct	6 stns (see also biotic components)	-	1 x 2	-	-	1 x 1	-
	Water quality measurements taken (surface and bottom samples) for pH, dissolved oxygen, suspended solids, turbidity/light penetration, inorganic nutrients	6.2 – 6.9	See related biotic components - fish, invertebrates and microalgae (required for interpretation of biotic data)		See related biotic components - samples can be collected as part of biotic survey		*In situ* measurements Accredited analytical laboratory		1 x 1	-
	Salinity profiles if mouth closes for longer than 1 month at a time	6.1	Mouth closed for longer than 1 month	6 stns	1 x 1	1 x1	-	-	1 x 1	-
HYDRODYNAMICS	Water level recordings	7.1 – 7.2	Continuous	Near mouth	Included in DWAF national monitoring programme				1 x 1	-
	Flow gauging	7.1 – 7.2	Continuous	Mandini gauging stn (plus additional downstream inflow)	Included in DWAF national monitoring programme				1 x 1	-
	Mouth observations in the low flow period by local residents	7.1 – 7.2	Daily	At mouth	-	-	-	-	1 x1	-
	Aerial photographs of estuary (earliest available year as well as most recent)	7.1 – 7.2	Annually to 2 yrs	Entire estuary	To be recommended for inclusion in the DEAT national coastal survey programme				1 x 1	-
	Water level recordings along the length of the estuary (done at the same time as cross section profile survey)	7.1 – 7.2 8.1 – 8.2	2 surveys in sampling year: spring & neap tidal cycles (2 wks each)	3 stns	-	1 x 2	-	1 x 1	-	1 x 1
	Velocity recordings over a spring & a neap tidal cycle (done at the same time as cross section profile survey)	8.1 – 8.2	2 surveys in sampling year: one day over a spring and neap tidal cycle	200 m upstream of mouth	-	3 x 4	-	1 x 3	1	-
SEDIMENT DYNAMICS	Series of cross-section profiles	8.1 -8.2	If >1000 m^3/s Survey after flood, else every 3 years in Sept/Oct	500 m intervals but with 0.5 m intervals at 1:2000 scale or better in mouth area	-	3 x 2	-	1 x1	1 x1	-
	Sediment grab samples for analysis of particle size distribution (PSD)	8.1 -8.2	If > 1000 m^3/s Survey after flood, else every 3 years in Sept/Oct	33 stns	1 x 1	-	-	R5000/survey	1 x1	-

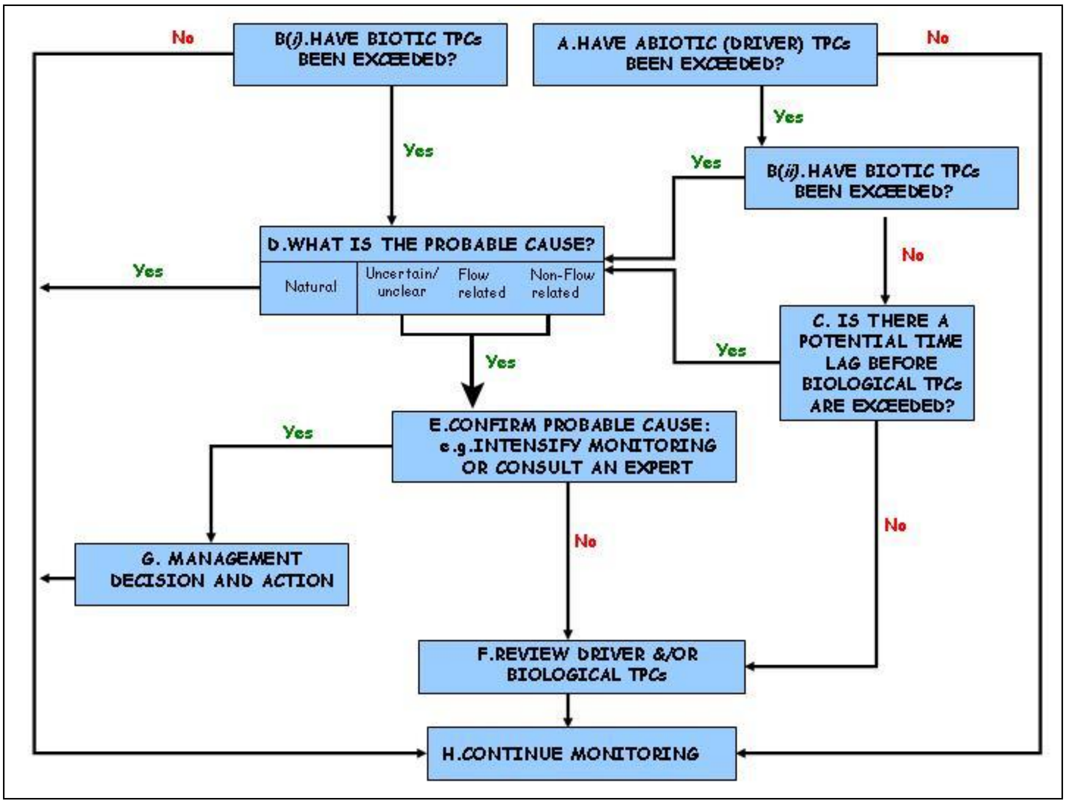
Table 21.10 Continued…

Ecological component	Monitoring action	Related TPC	Temporal scale (frequency and when)	Spatial scale (No. Stations)	Human Resources (as days/year)					
					Sampling		Analysis		Reporting	
					Scientist	Tech	Scientist	Tech	Scientist	Tech
	Continuous sampling of suspended sediments (maybe also organic) matter at the Mandini gauging weir with turbidity meter that was calibrated with the 5 year baseline data set (must be able to measure NTU similar to 50 000 mg/L).	8.1 – 8.2	Continuous (*in situ* turbidity meter)	Mandini gauging stn	1 x 1	1 x 12	1 x 1	-	1 x 1	-

21.4.2 Long-term Monitoring Decision Support System (DSS)

The proposed Monitoring Decision Support System (MDSS) to be applied in the long-term monitoring of estuaries, as part of the RDM process, is illustrated in Figure 21.1.

Fig 21.1 Proposed Monitoring Decision Support System (MDSS) to be applied in the long-term monitoring of estuaries



21.5 INTEGRATED PROGRAMME AND RESOURCE IMPLICATIONS

The tables below provide an estimated overall cost for the high priority baseline surveys (Table 21.13) and long-term monitoring programme per sampling year (Table 21.14). These budgets do not include travel costs, disbursements and VAT. Also, the cost of data management storage and management of the programme is not included.

Table 21.11 Estimated budget (in days) for baseline surveys (for high priority components – labelled blue/green in Table 23.11)

Component	Sampling				Analysis				Reporting			
	Specialist		Tech		Specialist		Tech		Specialist		Tech	
	Closed	Other	Closed	Other	Closed	Other	Closed	Other	Closed	Other	Closed	Other
Birds	1	-	-	-	-	-	-	-	1	1	-	-
Fish	2	1	2	10	1	-	2	5	3	3	-	-
Invertebrates	-	3	4	21	10	-	3	17	5	9	-	-
Macrophytes	-	-	-	-	-	-	-	-	-	-	-	-
Microalgae	4	-	4	-	8	-	12	-	8	-	-	-
Water quality	2	-	2	-	Accredited laboratories				2	1	-	-
Hydrodynamics	-	-		14	-	-	-	4	-	1	-	1
Sediment	-	1	-	20	-	1	-	1 plus R 37 000	-	4	-	-
Total	**9**	**5**	**12**	**65**	**19**	**1**	**17**	**27 plus R 37 000**	**19**	**19**	**-**	**1**

Table 21.12 Estimated budget (in days) for long-term monitoring programme per sampling year for high priority components – labelled green in Table 21.12

	Sampling		Analysis		Reporting	
	Specialist	**Tech**	**Specialist**	**Tech**	**Specialist**	**Tech**
Birds	-	-	-	-	2	-
Fish	3	5	-	2	1	-
Invertebrates*	-	4 (+6)	10	3 (+6)	5 (+2)	-
Macrophytes	1	1	2	3	1	1
Microalgae**	2 (+3)	2 (+3)	4 (+6)	6(+6)	8 (+ 4)	-
Water quality	1	3	Accredited laboratories		3	-
Hydrodynamics	-	14	-	4	1	1
Sediment	2	12	1	R 5000	2	-
Total	**9 (+3)**	**41 (+9)**	**17 (+6)**	**18 (+12) R 5000**	**23 (+6)**	**2**

* Resources in brackets only required if Varuna are absent from IFR sites where these were identified under the baseline study

** Resources in brackets only required if an algal bloom occurs in the estuary

Note that long-term monitoring for Estuaries is costed for one year.

22 IMPLEMENTATION OF THE RESERVE: REQUIRED HYDROLOGICAL INFORMATION

22.1 METHODS TO PROVIDE NATURAL TRIGGERS/CUES

There is a need to provide the natural triggers/cues, which are used to determine the Reserve requirements on a day-to-day (or month-to-month) basis. The natural trigger is used to determine the exceedence % point of the expected natural flow at any moment in time. This % point value is then used within the Reserve assurance rule table (specified as part of the gazetted Reserve) to fix the Reserve flow. Without this information it will be almost impossible to turn the gazetted Reserve determination into implementable information.

Within the Thukela catchment there is sufficient hydrological variability to suggest that no single trigger will suffice for all parts of the system.

The method that will eventually be implemented needs to be usable by a civil engineering technician. The output should be as close to real time as possible. Three possible methods have been identified.

22.2 Gauged Records

Make use of real time information from existing or new streamflow gauges to estimate the natural flow conditions and hence the exceedence % point.

22.2.1 Advantages

- Previous records provide the flow history and duration curve shape.
- Rated sections for new sites can provide a possible cost effective method of acquiring the necessary data.
- Real time data transmission requirements would be less than for real time rainfall data and modelling.
- Dealing with streamflow data directly, rather that simulated flows.

22.2.2 Disadvantages

- Historical records may not be stationary or accurate.
- Upstream impacts may be such that the gauge cannot be used to provide a reliable natural signal.
- If no suitable existing gauge can be found to represent a sub-region then it may be necessary to establish a new gauge or monitoring station. This will be potentially very expensive.

22.3 Real Time Monthly Simulation

Make use of real time rainfall (and other climatic data where necessary) in a calibrated monthly model for all required sites in the catchment.

22.3.1 Advantages

- An existing model calibration is available and is consistent with the flow data used to determine the Reserve and yield estimates.
- The modelling approach is more readily updateable than the system described in section 2 above.
- The information can be generated for the specific Reserve sites and therefore issues of transfer from one catchment to another are not relevant.
- The outputs have the potential to be used for other purposes (flood and drought warning, through rainfall forecasting).

- The need for the establishment of a reporting rain gauge network provides motivation for maintaining an accurate database of rainfall information.

22.3.2 Disadvantages

- The available reporting rainfall stations will be fewer than were originally used in the model calibrations and therefore it will be necessary to establish a rainfall 'model' for the region.
- There is no easy way of obtaining the short period information required to provide triggers for high flow releases. This is not such a disadvantage in the Thukela system as controlled releases from the main dams are not expected to be the main provider of the Reserve high flow requirements.
- It may be difficult to obtain sufficiently representative rainfall data from a limited set of reporting rain gauge stations. However, this problem has the potential to be resolved in the near future (i.e. the accuracy of the rainfall data could improve with time) using radar and remote sensing technology.

22.4 Real Time Daily Simulation

Make use of real time rainfall (and other climatic data where necessary) in a calibrated daily model for all required sites in the catchment.

22.4.1 Advantages

- The modelling approach is more readily updateable.
- The outputs have the potential to be used for other purposes (flood and drought warning, through rainfall forecasting).
- The need for the establishment of a reporting rain gauge network provides motivation for maintaining an accurate database of rainfall information.
- The daily modelling approach has the potential to provide the cues for future real time releases of high flows.
- The information can be generated for the specific Reserve sites and therefore issues of transfer from one catchment to another are not relevant.

22.4.2 Disadvantages

- The available reporting rainfall stations will be fewer than were originally used in the model calibrations and therefore it will be necessary to establish a rainfall 'model' for the region.
- It may be difficult to obtain sufficiently representative rainfall data from a limited set of reporting rain gauge stations. However, this problem has the potential to be resolved in the near future (i.e. the accuracy of the rainfall data could improve with time). This has the potential to be a bigger problem than with the monthly modelling approach.
- The initial calibration and model set up procedures will be more time consuming and expensive than the monthly modelling approach.

22.5 SPECIFIC RECOMMENDATIONS

Either of the modelling approaches have distinct long-term advantages, which will be applicable not only to the Thukela system, but to every other catchment in the country. The main advantages are that the approach is flexible, has value beyond the immediate objectives of implementing the Reserve, and can be established as a generic methodology for any catchment. The modelling approaches have the additional advantage of being able to make use of the results from WRC supported research projects that are expected to be completed within the next few years (for example; spatial rainfall generation methods, WR2005 and associated improvements to land use and model parameter databases, as well as improvements to the Pitman model itself).

The gauged records approach should be the one that requires the least resources to establish, although this is partly dependent on the number of new gauging sites that will be required. However, this approach does not offer any additional advantages over and above the immediate requirements of providing the Reserve triggers.

There is no doubt that the two modelling approaches require more resources to establish (and the daily model the most). However, they also offer far greater long-term benefits in terms of the integrated management of water resources in the Thukela (and other rivers) basin. There are many overlaps in the two modelling approaches and it is possible to start with the slightly simpler monthly approach and move to the more detailed daily approach at a later date when required.

22.6 METHOD REQUIREMENTS

The requirements for each method are provided below in the format of brief terms of references.

22.6.1 Gauged Records Method

6.1.1 For each IFR site that will be used for implementation and monitoring identify a gauged stream flow site that can be considered representative of the natural flow characteristics at the IFR site. This implies that observed flow duration curve characteristics are either similar to the expected natural flow duration curve characteristics at the IFR site, or that corrections (naturalisation) can be made to make them similar.

6.1.2 If a site is available, the stream flow record should be checked for stationarity and accuracy and the upstream impacts quantified as accurately as possible.

6.1.3 Establish any corrections that need to be applied to ensure that an observed flow can be translated into a natural flow duration curve % point. This will always be a problem where the observed flow duration curve has any extended flat components (such as is the case with extended periods of zero flow).

6.1.4 Develop the procedures for real time collection of flow data on a daily basis, through either telemetry systems or site visits.

6.1.5 Develop the software required to update the database of observed flows, translate any observed flow into a corrected duration curve % point and interpolate into the Reserve assurance rule table to provide the required Reserve flow at any point in time.

6.1.6 If such a site is not available, locate a river site where a rated section can be established, survey the cross-section and carry out a detailed hydraulic calibration based on at least three measured flows. Components 1.6 to 1.9 must then be included.

6.1.7 Develop procedures and software that can be used to improve the hydraulic calibration over time based on periodic flow measurements designed to cover a wide range of flow conditions.

6.1.8 Establish and calibrate a hydrological model of the present day condition and simulate a reasonably long period of flows to use as a basis for establishing the present day flow duration curve characteristics. As data are collected over time, this calibration should be checked and improved.

6.1.9 Components 6.1.3 to 6.1.5 also need to be undertaken for a newly established site.

22.6.2 Monthly Rainfall-Runoff Model Approach

6.2.1 The first task is to identify rainfall gauging stations within the catchment that can be used as, or converted to, real time reporting stations and develop the procedures for transmitting rainfall on a daily basis to the control office.

6.2.2 It is inevitable that the number of reporting rain gauge stations will be fewer than those used in the initial model calibration. It is therefore necessary to develop a model of spatial rainfall based on the reporting stations that can provide a similar input to the rainfall-runoff model as the set of stations used for the original model calibration.

6.2.3 The availability of near real time, additional hydrometeorological data (temperature, evaporation, etc.) should be identified and a procedure for incorporating such inputs into the model developed.

6.2.4 The original model calibrations will need to be refined to account for any differences in the hydrological forcing data (rainfall, evaporation).

6.2.5 The model software will need to be packaged in a way that allows for additions to be made to the rainfall and evaporation input database, the model run and the results interrogated in a user friendly manner. Some database error checking routines will also be required. Although the model operates on a monthly time step, it is proposed to update the rainfall data more frequently (once a week, or every 10 days, for example). The model software will have to account for this and a simple rainfall ‘forecasting’ process for the remaining part of the month may have to be included.

6.2.6 The software will also have to integrate the real time estimates of natural flow with the Reserve assurance table to provide an estimate of the Reserve flow requirement.

6.2.7 The monthly model approach should be satisfactory for all the low flow Reserve requirements, but if high flow release information is required, additional methods will have to be developed. It is not clear at this stage what form these will take.

6.2.8 The previous 7 tasks are all required to establish the basics of the real time management system. However, there are additional tasks that could be undertaken after implementation that could improve the accuracy of the estimates. Most of these relate to improving the estimates of the area distribution of rainfall. Recent research results (Prof. G Pegram) suggest that the combined use of radar, satellite and ground based rainfall observations could lead to improved real estimates of rainfall. The application of these technologies in the field of real time management of the Reserve needs to be investigated.

22.6.3 Daily Rainfall Runoff Model Approach

The tasks under this approach are almost identical to those for the monthly modelling approach. The details of some of the tasks may be somewhat different and more time-consuming. The points below therefore highlight these differences rather than repeating the task descriptions.

6.3.1 ACRU model has already been configured for the Thukela catchment and it therefore seems logical to use this model as the starting point for the real-time management system. However, the existing results are not comparable with the flow data that are being used for planning and management of the Thukela system. It would therefore be necessary to modify the ACRU model set-up to generate results that are consistent with the current inputs to the yield model and the data that were used to determine the Reserve requirements. It is also recommended that comparisons be made with gauged data so that potential problems with the existing inputs to the yield model (based on Pitman model simulations) can be flagged for future attention.

6.3.2 The procedures for developing the spatial rainfall model will be more complex with daily data and greater care will have to be taken to ensure that isolated extreme values measured at the reporting stations are not falsely extrapolated to ungauged parts of the basin.

6.3.3 The daily model offers opportunities for triggering high flow release requirements and it will be necessary to incorporate these methods into the overall software package. This should not be a problem, as a modelling strategy (the Daily IFR model included in SPATSIM) to achieve this already exists.

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