

THUKELA WATER PROJECT DECISION SUPPORT PHASE

RESERVE DETERMINATION MODULE THUKELA SYSTEM ECOLOGICAL SCENARIO (RIVERS) REPORT

March 2004

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This report is to be referred in bibliographies as:

Department of Water Affairs and Forestry, South Africa. 2004. DWAF Report No. PBV000-00-10309. Thukela System Ecological Scenario Report - Reserve Determination Study - Thukela River System. Prepared by IWR Source-to-Sea as part of the Thukela Water Project Decision Support Phase.

First draft: May 2003

Comments from reviewer: May 2004

Final report: March 2004

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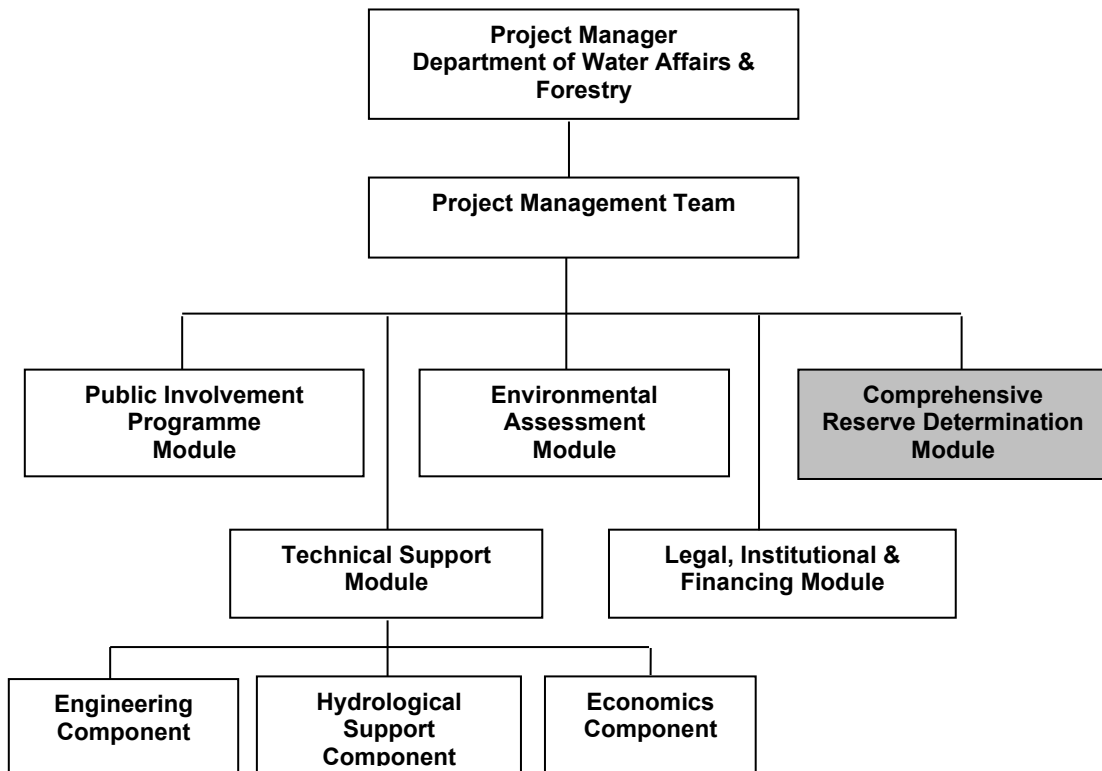
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STRUCTURE OF DECISION SUPPORT PHASE



**DEPARTMENT OF WATER AFFAIRS & FORESTRY
NATIONAL WATER RESOURCE PLANNING**

**THUKELA WATER PROJECT DECISION SUPPORT PHASE
RESERVE DETERMINATION MODULE THUKELA SYSTEM
ECOLOGICAL SCENARIO (RIVERS) REPORT**

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MARCH 2004

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ACKNOWLEDGMENTS

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DWAF (Directorate: Water Resource and Planning and the Directorate: Resource Directed Measures) and the TWPDSP Project Management Team for their participation and contribution:

Mr Jeremy Cooke	Tlou & Matji
Ms Adhishri Singh	Directorate: RDM
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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.

The Reserve Determination module involves quantification of the water resource required to meet objectives for the Thukela system under a series of scenarios that 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:

- Develop scenarios and test these with the DWAF and stakeholders;
- recommend one of these scenarios to represent the Ecological Reserve for the quality, quantity components for the river and estuary;
- determine the impact of the recommended Reserve on the allocatable yield;
- determine whether it is possible to supply the Reserve from existing and proposed Schemes;
- and to provide mitigation measures if it is not.

PURPOSE OF THIS REPORT

The main objective is the following:

To determine the ecological (or more correctly biophysical) consequences of different flow scenarios at each IFR site.
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NOTE: The same scenarios were tested to determine the ecological consequences on the Estuary (DWAF 2004c).

APPROACH

The following sequence was adopted to achieve the above objective.

- Evaluate impact of the IFRs on the yield of the system.
- Design additional flow scenarios.
- Formulate final scenarios for evaluation purposes.
- Ecological evaluation of different flow scenarios.
- Compare results.

PROCESS

- **Scenarios requiring evaluation:** As the number of scenarios were too numerous and in some cases too similar to evaluate each one separately, an initial evaluation based on the flow duration graphs was made to identify the similarities. If necessary, these were checked using the FS-R profiles. Similar scenarios were assessed as one.
- **Scenarios converted to stress profiles:** Each scenario to be evaluated at IFR 1 was converted to stress and the wet and dry season stress profiles provided in graph form.

- **Resulting ECs for each scenario:** The resulting categories for each component and for the Ecstatus were provided i.e. (Present Ecological EC (PES), the category that would result if there was a long-term (20 year) trajectory of change, the recommended Ecological Reserve Category and the ERCs per component representing an Ecstatus lower than the recommended ERC).
- **Consideration of non-flow related issues:** A qualitative rationale for the changes in category which would result when non-flow related issues are considered are provided.

Geomorphological evaluation and assumptions: The determination of consequences on events is problematic as the output is provided as monthly volumes and not daily data. The distribution of the monthly volume between base flows and flood events is unknown. It is therefore assumed that for scenarios with more water than the recommended IFR, flow peaks will increase *pro rata*, and that for scenarios with less flow, flow peaks will decrease *pro rata*. If some other management regime is applied (i.e. more or less base flows rather than peaks), the predicted geomorphological ERC categories will not apply, since flow peaks are responsible for most of the sediment transport.

Water quality evaluation and assumptions

Water quality evaluations were conducted based on the following assumptions and conditions.

- Non-flow related problems, and source-directed controls required to improve water quality conditions, are included in the assessments as the process is not intended to use flow to dilute water quality issues.
- Modelled variables showing a concentration-flow relationship, with a r^2 value of at least 0.65. All values given using modelling are APPROXIMATE. All predictions made of water quality under different flow scenarios assume that pollution will be at the current loading rates.
- Where scenarios are ECd as being equivalent, this is in water quality terms only. Variations can be seen in terms of flow regime.
- TDS consequences were assessed following Approach 1, i.e. using the TDS-toxicity table based on NaCl tests. These tables show a B category of 200 – 600 mg/L for TDS, but it may be more valid to set a B category of 200 – 400 mg/L as salt problems are sulphate based, and the natural levels throughout the catchment are very low. It is noted in the text where these adjustments are applied.
- **NOTE:** Other specialist components, e.g. fish, biota etc., are assessing scenarios based on stress, whereas water quality is based on modelled *median* values.
- Water quality consequences were assessed under different scenarios using the following methods: TDS – using NaCl toxicity tables to set categories; TIN, sulphate and magnesium sulphate – using Approach 2 to set categories (i.e. using the mean weighted Reference Condition to benchmark tables, and the Present Ecological EC weighted 95%ile to set the category – see DWAF, 2002 and DWAF 2004a, (DWAF Report No. PBV000-00-10306) for details.
- The following assessment categories were used during the evaluation. These categories are related to those in DWAF, 2002 – additional categories were generated by the water quality team. Both the descriptive and A - F classification system are shown.

TIN categories relating different descriptors:

Natural	A category	<=0.25 mg/L
Upper Good	A/B	<=0.5
Good	B	<=0.75
Lower Good	B/C	<=1
Upper Fair	C	<=2
Fair	C/D	<=3
Lower Fair	D	<=4
Poor	E/F	>4

SRP categories relating different descriptors:

Natural	A category	<=0.005 mg/L
Upper Good	A/B	<=0.012
Good	B	<=0.020
Lower Good	B/C	<=0.025
Upper Fair	C	<=0.058
Fair	C/D	<=0.091
Lower Fair	D	<=0.125
Poor	E/F	>0.125

FLOW SCENARIOS

The flow scenarios were devised by the client, the Reserve Team and the system hydrologists (Water Resources Planning (WRP)). A short description of each scenario is provided below.

- **Present Day (2000 Development):** Each scenario will be analysed for the Present Day (2000 development) except scenario 7 and 8, which will be analysed at the 2015 development.
- **Scenario 1:** Sc 1 models the Present Day as described above and supplies the IFRs as a priority at the Upper ERC level.
- **Scenario 2:** This scenario is the same as Sc 1; however all IFRs are supplied at the Recommended ERC level.
- **Scenario 3:** This scenario is the same as Sc 1; however all IFRs are supplied at the ERC lower than the recommended.
- **Scenario 4:** This scenario is modeled using the 2000 Present day. The scenario is in essence a modification of Sc 2, i.e. all IFRs are supplied for the Recommended ERC with the following changes:
 - Use the lowest category (C/D) at IFR site 4.
 - Reduce drought flows at IFR site 3, (Little Thukela River) 7 and 8 (Sundays River) by half.
 - Reduce maintenance low flows in June, July and August for all sites on the Mooi River (Sites 10, 11 and 12).
 - For IFR sites 15 and 16 where scenario requirements exceed Present Day Sc 7 flows, flows were reduced to present day flows.
- **Scenario 5:** This scenario is essentially the same as scenario 4 with low assurance high flow (floods) removed from all sites.
- **Scenario 6:** This scenario is the same as for scenario 5 but all the Reserves (apart from IFR 4 which is still applied at a C/D category) are supplied at the lower ERCs.
- **Scenario 7:** This scenario represents a different version of present day than the present day described under 3.1. The Sc 7 description is similar to the 2000

Present Day, however, the operating releases are now incorporated and operation of the dams will therefore not be demand driven.

- **Scenario 8:** Sc 8 is a theoretical scenario to serve as a worst-case scenario. It represents 2015 development with NO IFR releases.

SCENARIOS SELECTED FOR ECOLOGICAL CONSEQUENCES EVALUATION

The eight scenarios described were evaluated and it was decided that the following scenarios would not be included for the ecological consequences evaluation:

- Scenario 1: This scenario represented an unrealistic scenario as it focused on ERCs which are higher than those recommended by the ecological specialists and, when one considers the practicalities, would be unlikely to be achieved.
- Scenario 4: This scenario is similar to Sc 5. Sc 5 however does not include the large floods as part of the IFR requirement and is therefore a more realistic scenario than Sc 4. As the objective of this phase of the study is to identify and evaluate realistic scenarios, which include considering impact on the yield as well operational constraints, Sc 4 does not warrant further investigation.

SCENARIO 9 ANALYSIS

Necessity for an additional Scenario

During the analysis of the results generated at each IFR site, it became obvious that even Sc 6, which impacts least on the yield (apart from Sc 7 and Sc 8 which are not realistic scenarios and do not include any Reserves) and has a minimal impact on the ecology, still provides more water at various IFR sites. It was therefore decided to create an additional scenario to attempt to optimise the existing Sc 6 and thereby decrease the impact on yield of Sc 6. The new scenario is referred to as Sc 9. Sc 9 was modelled as for Sc 6 apart from the Little Thukela and Mooi Rivers. The ERC was not achieved in these tributaries for Sc 6 but was achieved in Sc 5. Sc 5 was therefore run for these tributaries. Sc 6 has the least impact on yield for the other users. The optimal solution in yield terms lies between Sc 6 and 9. Additional floods that could not be supplied were removed.

Description of Sc 9

Scenario 9 was devised during a meeting consisting of the WRYM modellers and key members of the Reserve team. Sc 6 was used as a baseline and the changes that are required are illustrated in the table below.

ECOLOGICAL EVALUATION

The ecological evaluation was undertaken and is summarised in the table below.

Analysis of IFR sites at which the recommended ERCs have been achieved

Scenarios	Worse [#]	%	Same ^{&}	%	Better [*]	%
Sc 2	1 (IFR 4 ¹)	6.67	6	40.00	8	53.33
Sc 3	4 (IFR 3,4,10,11)	26.67	4	26.69	7	46.67
Sc 5	1 (IFR 4)	6.67	7	46.67	7	46.67
Sc 6	4 (IFR 3,4,10,11)	26.67	6	40.00	5	33.33
Sc 7	9	60.00	3	20.00	3	20.00
Sc 8	13	86.67	1	6.67	1	6.67
Sc 9	1 (IFR 4)	6.67	9	60.00	5	33.33

* Amount of IFR sites better than the ERC.

& Amount of IFR sites the same as for the recommended ERC.

Amount of IFR sites worse than the recommended ERC.

¹ IFR 4 in all cases do not meet the recommended ERC which in this case is an improvement of the PES. However, for Sc 2,3,5,6 and 9 it DOES meet the PES.

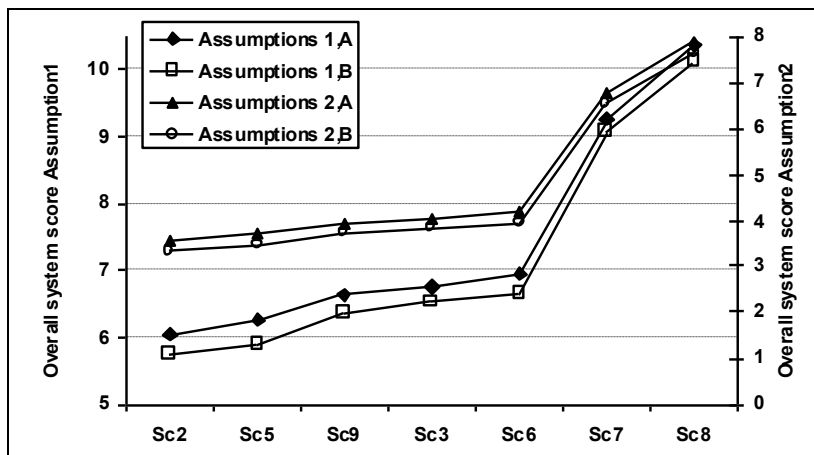
Multi Criteria Decision Analysis

The MCDA was investigated to determine whether this process could allow for more appropriate decision making regarding the preferred scenario. This exercise was a test and the purpose was to determine whether this tool has any merit in future Reserve applications.

The scenario analysis showed that the resultant scores and rank order of the scenarios was insensitive to the assumptions regarding the conversion from the alphabetic ERC category to a score, and the weights given to the sites seen in the figure below.

A summary of results of the MCA is provided in Appendix A.

Overall status of the river for the different scenarios under the four different assumptions described in Chapter 19.



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ACRONYMS AND ABBREVIATIONS

DWAF	Department of Water Affairs and Forestry
EIS	Ecological Importance and Sensitivity
ERC	Ecological Reserve Category
FAII	Fish Assemblage Integrity Index
FS-R	Flow Stressor Response
IFR	Instream Flow Requirement
MCA	Multi-criteria Analysis
PES	Present Ecological EC
PMS	Plant Moisture Stress
PMT	Project Management Team
RDM	Reserve Directed Measures
RU	Resource Unit
Sc	Scenario
SRP	Soluble Reactive Phosphorous
TIN	Total Inorganic Nitrogen
Traj	Trajectory
TWPDSP	Thukela Water Project Decision Support Phase
WRP	Water Resources Planning
WRYM	Water Resources Yield Model

1 INTRODUCTION AND 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 the DWAF.
- The specific requirements of the Terms of Reference as supplied by the 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 that 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:

- Develop scenarios and test these with the DWAF and stakeholders;
- recommend one of these scenarios to represent the Ecological Reserve for the quality, quantity components for the river and estuary;
- determine the impact of the recommended Reserve on the allocatable yield;
- determine whether it is possible to supply the Reserve from existing and proposed Schemes;
- and to provide mitigation measures if it is not.

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, DWAF Report No. PBV000-00-10302).
- Determine the PES, the EIS and the ERC for each Resource Unit (DWAF, 2003b, DWAF Report No. PBV000-00-10303).
- Determine the Basic Human Needs Reserve (DWAF, 2003c, DWAF Report No. PBV000-00-10305).
- Determine the IFR and quality requirements for different ERCs.

The IFRs have been quantified for various ERCs. However, the flows must now be tested to determine the following:

Are the IFRs at the recommended ERCs available or in conflict with other requirements?

If the IFRs are in conflict with other requirements, could the IFR be adjusted to minimise impact on the ecology and on other users?

Can the IFRs be supplied, i.e. are there operational constraints in the system? For example, if a certain flood requirement is required downstream of an existing dam, but the outlets are not big enough to supply these floods, the flood volume must be removed from the IFRs.

1.1 PURPOSE OF THIS REPORT

The report consists largely of the results of a specialist meeting held on 27 and 28 January 2003 to determine the ecological consequences of each scenario on rivers. It must be noted that the same scenarios were tested to determine the ecological consequences on the Estuary (DWAF 2004d).

The purpose and objective of the report is to

- Document the approach followed.
- Provide the sequential actions undertaken during the specialist meetings to produce the results and to provide a detailed explanation of the format of the report chapters for each IFR site in which the results are provided.
- Describe the ecological consequences of each scenario at each IFR site.
- Provide conclusions and a derived optimum scenario.

1.2 STRUCTURE OF THE REPORT

Chapter one is this chapter providing background and an introduction.

Chapter two provides the approach and describes the format of Chapters 4 to 17.

Chapter three provides a summarised description of the scenarios.

Chapter four to seventeen describes the results on a site-by-site basis.

Chapter eighteen provides the necessity, description, evaluation, processes and consequences of the additional scenario.

Chapter nineteen provides the conclusions and documents the decision on the optimum scenario as derived after the specialist meeting in January 2003.

2 APPROACH

2.1 OBJECTIVE OF THIS STUDY¹

The main objective is the following:

To determine the ecological (or more correctly biophysical) consequences of different flow scenarios at each IFR site.

2.2 APPROACH

The following sequence was adopted to achieve the above objective.

2.2.1 Evaluate impact of the IFRs on the yield of the system

Previously, IFRs were assessed for various ecological river ECs, called Ecological Reserve Categories (ERCs). During this assessment, no consideration is given on whether the IFRs are available, can be managed or supplied. Various alterations of the IFR to achieve the same objective or ERC were also not considered. It must be noted that a number of different flow regimes can achieve a specific objective. For practical reasons, one flow regime (IFR) to achieve or maintain the ERCs is set and other flow regimes are tested against the IFRs.

During this study, the availability of flows were tested, utilising a systems model, the Water Resources Yield Model (WRYM). IFRs to achieve a range of ERCs were prepared for each site. These consisted of an IFR to achieve a higher than recommended ERC, one to achieve the recommended ERC, and one to achieve an ERC lower than the recommended ERC (See table 3 2). The WRYM models the IFRs as priority so that the impact on the yield and therefore on other users (present and/or future) can be assessed. The way that the model is set up is decided upon with ecological specialists and described in report no PBV000-00-127/02 (WRP, 2001).

2.2.2 Design of additional flow scenarios

The modelers and the ecological specialists assess the impacts of the IFRs on the yield. Knowing now where potential shortages exist as well as the IFR characteristics that cause the shortages; potential changes to the IFRs are suggested. At this stage the operational constraints are also considered in the adjustments to the IFRs. Examples of such constraints are the following:

- Existing dams with limited outlet capacity.
- Existing dams far upstream from IFR sites, i.e. released floods could be attenuated.
- Downstream demand, i.e. domestic water supply that has to be supplied at high assurance and uses the river as a conduit.
- No large operating structures – only abstractions by means of pumping for example. No flows can therefore be ‘released’, low/base flows can only be managed by restricting demand.
- Any international agreements which could be seen as an existing constraint.

The flow scenarios designed at this stage are described in Chapter 3 of this document and more detail provided in report no PBV000-00-127/02 (WRP, 2001).

¹ This study’ refers to the ‘ecological evaluation of different flow scenarios’ phase of the Thukela Reserve Determination Study

2.2.3 Formulation of final scenarios for evaluation purposes

Evaluating scenarios, modeling them and adjusting the scenarios (as described in 1.2.1 and 1.2.2) can be an interactive process. Timing, the severity of the impacts, complexity and budgets are factors to take into consideration to determine the number of iterations and scenarios required. In the case of the Thukela, initially only one round was deemed sufficient. However, at a later stage it was decided that an additional optimised (from both the ecological and user point of view) scenario was required and this scenario as well as the results of the ecological evaluation are documented in chapter 18.

2.2.4 Ecological evaluation of different flow scenarios

The ecological evaluation is based on an assessment of the impact on the ECs or Ecological Reserve Categories (ERCs) recommended for each component as well the overall EC (Ecostatus).

The tools used to undertake the evaluation are the following:

- Flow duration graphs for the wettest and driest flow months consisting of graphs for natural flow, present day, the IFRs and each flow scenario to be evaluated.
- Stress duration graphs (stress profiles) of the wet and dry season illustrating the natural, present day and flow scenario stress profiles. (The Flow-Stressor Response (FS-R) method is described in DWAF, 2004b (DWAF Report No. PBV000-00-10307)).
- Stress indices for each component providing all the descriptions for stresses ranging from 0 - 10 as well as the motivations for the stress levels at specific durations that were selected to represent the requirements for each component in each category.

The process followed prior to and during the specialist meeting are sequentially described below:

- The flow duration graphs were provided to specialists.
- (The FS-R profiles were provided to specialists – this was not available prior to the specialist meeting in this study.)
- Specialists compare the stresses associated with each scenario against the characteristic stresses for each of the IFRs for the various categories as provided during the IFR specialist meeting. If the FS-R graphs are available prior to the specialist meeting, this will be undertaken prior to the specialist meeting. In the case of the Thukela, this was undertaken during the specialist meeting.
- Specialists determine which category each scenario represents for their components. An example of this process would be as follows. Fish required a stress of 5 to occur for 60% of the time to achieve a C category. It was also determined that a stress of 5 that occurs for 50% of the time would represent a D category. The scenario to be evaluated consists of a stress of 5 that occurs for 57% of the time. An evaluation must now be made whether this still represents a C category, a C/D or a D category and the motivation for the decision must be supplied. This is an over-simplified example as a variety of stresses and durations would normally be identified during both the wet and dry season and the high flows would also be evaluated. NOTE: During this assessment, the emphasis was, where possible, only on flow-related consequences. It must be noted however that it is especially difficult in some cases to disentangle the flow and non-flow related issues for the geomorphological assessment. Furthermore, the process (rules/guidelines/criteria followed to decide on the categories) varied for different circumstances at different sites and different specialists and requires further method development. (see last bullet)

- The various component categories for each flow scenario were then evaluated to determine the Ecostatus. The initial process used was to compare all the component ECs, identify the significant drivers and, by means of discussion, agree on an Ecostatus. This was then checked against the FS-R profiles which have been previously determined and which represent certain EcoECs. These of course provide an indicator of what the resulting Ecostatus category should be and are used as guidance. If, for example, the stress profiles for a C and D ERC have previously been defined, a C/D line would lie mostly between the C and D. If the scenario were to be evaluated as a B/C, such an assessment should be carefully reassessed, as likely to be wrong. This is however an over-simplification as the scenarios to be evaluated seldom represent a linear change. For 20% of the time the line might lie above the predefined stress profile (i.e. representing lower flows), for 30 % of the time on the line, and for 50% of the time below (i.e. representing higher flows). The ecological significance of the scenario profile should then be evaluated to determine which Ecostatus categories the scenario represents.
- An assessment was also made of how likely it would be that these evaluated ECs would be achieved when non-flow related issues are taken into account. This is done in a descriptive and probably subjective way at this stage.

2.2.5 Comparison of results

The assessments were then compared in a variety of ways to evaluate which scenario will be the most realistic from an ecological point of view. During the Thukela specialist meeting, the following process was followed:

- The Ecostatus of each IFR site for each scenario was compared on a matrix.
- The results were analysed in a spreadsheet according to how many IFR sites for each scenario would achieve the recommended ERC, would be better than the recommended ERC, and worse than the recommended ERC.
- Multi Criteria Decision Analysis was also applied (for detail see Appendix A)

It must be noted that this comparison and ecological recommendation are only one component of a much larger process to decide on a particular scenario. The economic consequences and stakeholder desires amongst others must also be considered.

2.3 PRESENTATION OF RESULTS

For illustrative purposes, Chapter 4 depicting the IFR 1 results is used here as an example. The headings in brackets therefore illustrate the corresponding Chapter 4 headings.

2.3.1 (4.1) Scenarios requiring evaluation

As the number of scenarios were too numerous and in some cases too similar to evaluate each one separately, an initial evaluation based on the flow duration graphs was made to identify the similarities. If necessary, these were checked using the FS-R profiles. Where scenarios were close, only one scenario was assessed.

2.3.2 (4.2) Scenarios converted to stress profiles

Each scenario to be evaluated at IFR 1 was converted to stress and the wet and dry season stress profiles provided in graph form. In all cases the following colour code was used:

Dark blue: Reference
Red: Modelled Present Day

An example of such a graph is provided in Figure 4.1

2.3.3 (4.3) Resulting ECs for each scenario

The resulting categories for each component and for the Ecstatus were provided in a figure (see Figure 4.2). The results used for comparison purposes were also provided. These are the Present Ecological EC (PES), the category that would result if there was a long-term (20 year) trajectory of change, the recommended Ecological Reserve Category and the ERCs per component representing an Ecstatus lower than the recommended ERC. This column is not provided in Figure 4.2 as the recommended ERC is a D and a lower Ecstatus evaluation was not considered.

Some of the component blocks are marked with black flags. The black flag indicates an Ecstatus which is unrealistic when intransigent non-flow related issues, are taken into account. An evaluation of the resulting categories if the non-flow related issues are taken into account is provided in Chapter 19. Also refer to 2.2.4, last bullet.
















2.3.4 (4.4) Sc 5 consequences

The component with the resulting category associated with Sc 5 is provided as a heading. For each component the reasoning used to determine the category. The same process and documentation are provided for each scenario.

2.3.5 (4.7) Comparison of scenarios

The tables used to present stakeholders are provided as a summary and a comparison of each scenario against the recommended ERC. The figure (Figure 2.1) is provided below with an explanation. (This figure is a copy of Figure 4.3 and is specific to IFR 1).

Fig 2.1 Comparison of the ecological consequences of scenarios

Sc	EC	Worse				Same			Improved			
2,3,5,6 ↑	C/D											
7 ↔	D											
8 ↓	E											

- Column one is headed Sc and lists each different scenario in a row. The arrows indicate whether the scenario would result in an Ecstatus which is an improvement on the ERC (arrow pointing to the top of the page), the same as the ERC (horizontal arrow), or worse than the recommended ERC (arrow pointing to the bottom of the page).
- Column two provides the Ecstatus category which would result from each scenario.
- Column three is headed “Improved” and provides icons for each component which would improve within the Ecstatus, for each scenario.
- Column four headed “Worse” and provides icons for each component which would deteriorate beyond the recommended ERC.

- Column five headed “Same” and provides icons for each component, which would remain the same as the recommended ERC.

2.3.6 (4.8) Consideration of non-flow related issues

This section provides a qualitative rationale for the changes in category which would result when non-flow related issues are considered.

2.4 GEOMORPHOLOGICAL EVALUATION AND ASSUMPTIONS

The determination of consequences on events is problematic as the output is provided as monthly volumes and not daily data. The distribution of the monthly volume between base flows and flood events is unknown. It is therefore assumed that for scenarios with more water than the recommended IFR, flow peaks will increase *pro rata*, and that for scenarios with less flow, flow peaks will decrease *pro rata*. If some other management regime is applied (i.e. more or less base flows rather than peaks), the predicted geomorphological ERC categories will not apply, since flow peaks are responsible for most of the sediment transport.

2.5 WATER QUALITY EVALUATION AND ASSUMPTIONS

Water quality evaluations were conducted based on the following assumptions and conditions.

- Non-flow related problems, and source-directed controls required to improve water quality conditions, are included in the assessments as the process is not intended to use flow to dilute water quality issues.
- Modelled variables showing a concentration-flow relationship, with a r^2 value of at least 0.65. All values given using modelling are APPROXIMATE. All predictions made of water quality under different flow scenarios assume that pollution will be at the current loading rates.
- Where scenarios are ECd as being equivalent, this is in water quality terms only. Variations can be seen in terms of flow regime.
- TDS consequences were assessed following Approach 1, i.e. using the TDS-toxicity table based on NaCl tests. These tables show a B category of 200 – 600 mg/L for TDS, but it may be more valid to set a B category of 200 – 400 mg/L as salt problems are sulphate based, and the natural levels throughout the catchment are very low. It is noted in the text where these adjustments are applied.
- **NOTE:** Other specialist components, e.g. fish, biota etc., are assessing scenarios based on stress, whereas water quality is based on modelled *median* values.
- Water quality consequences were assessed under different scenarios using the following methods: TDS – using NaCl toxicity tables to set categories; TIN, sulphate and magnesium sulphate – using Approach 2 to set categories (i.e. using the mean weighted Reference Condition to benchmark tables, and the Present Ecological EC weighted 95%ile to set the category – see DWAF, 2002 and DWAF 2004a, (DWAF Repot No. PBV000-00-10306) for details). Water quality assessment categories shown on tables in this report are consistent with the Water Quality Report (PBV-000-00-10306) and methods of DWAF, 2002 followed for the present EC assessment.
- The following assessment categories were used during the evaluation. These categories are related to those in DWAF, 2002 – additional categories were generated by the water quality team. Both the descriptive and A - F classification system are shown.

TIN categories relating different descriptors:

Natural	A category	≤ 0.25 mg/L
Upper Good	A/B	≤ 0.5
Good	B	≤ 0.75
Lower Good	B/C	≤ 1
Upper Fair	C	≤ 2
Fair	C/D	≤ 3
Lower Fair	D	≤ 4
Poor	E/F	> 4

SRP categories relating different descriptors:

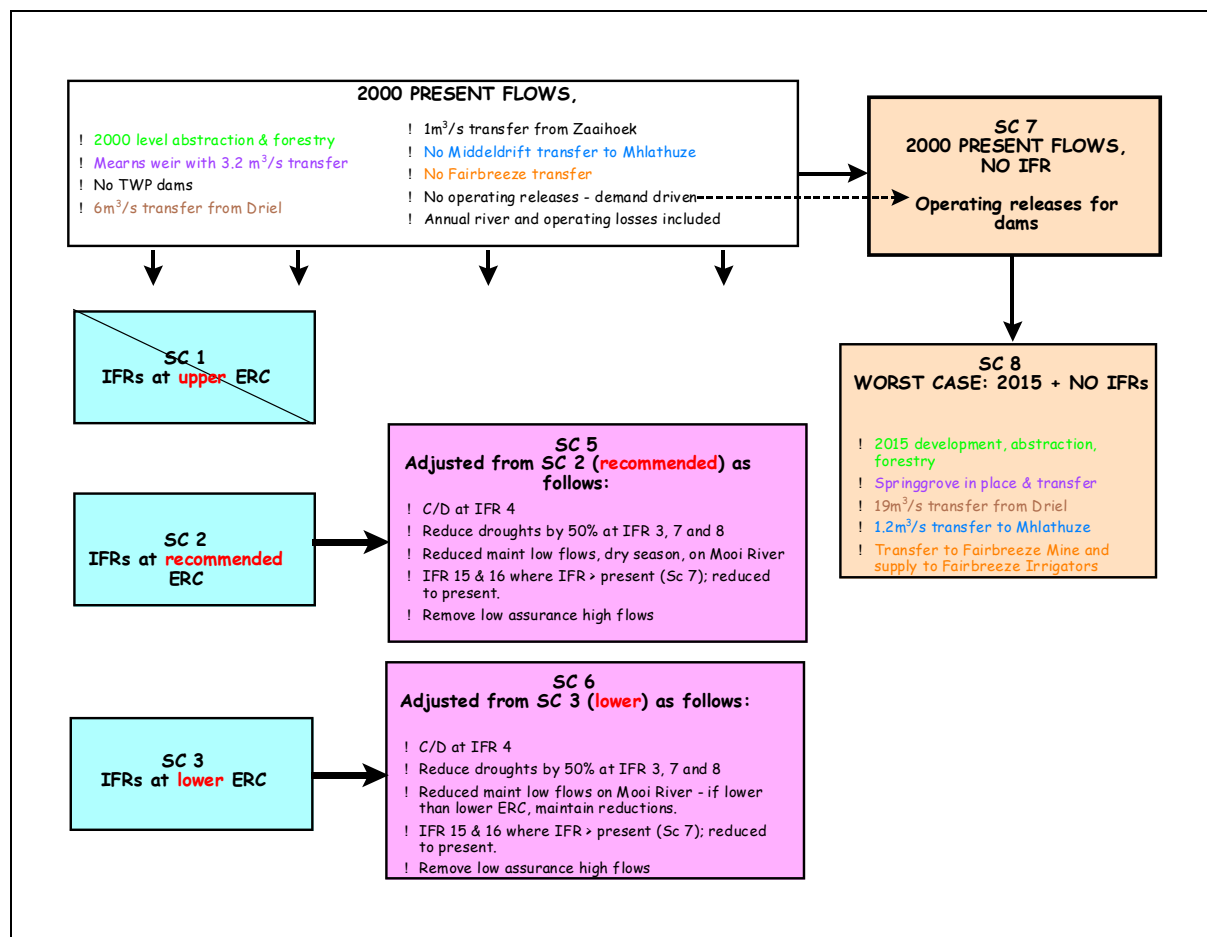
Natural	A category	≤ 0.005 mg/L
Upper Good	A/B	≤ 0.012
Good	B	≤ 0.020
Lower Good	B/C	≤ 0.025
Upper Fair	C	≤ 0.058
Fair	C/D	≤ 0.091
Lower Fair	D	≤ 0.125
Poor	E/F	> 0.125

3 FLOW SCENARIOS

The flow scenarios were devised by the client, Reserve Team and the system hydrologists (Water Resources Planning (WRP)). These scenarios are fully described in WRP documentation, Report no PBV000-00-127/02 (WRP, 2001).

As provided by WRP, the scenarios are described below and illustrated in Figure 3.1.

Fig 3.1 Description of scenarios



3.1 PRESENT DAY (2000 DEVELOPMENT)

Each scenario will be analysed for the Present Day (2000 development) except scenario 7 and 8, which will be analysed at the 2015 development. The Present Day development level is described below:

- 2000 Development level abstractions and aforestation usage.
- Mearns Weir is in place (No Springgrove Dam present) with a maximum transfer from Mearns to Midmar Dam of 3.2m³/s.
- No TWP dams in place.
- 6m³/s being transferred from Driel Barrage to the Vaal River catchment, with no support from the Clifford Chambers weir.
- 1m³/s transfer from the Zaaihoek Dam to the Vaal River catchment and Majuba Power Station.
- No transfer from Middeldrift to the Mhlathuze River catchment.
- No transfers to Fairbreeze Mine.

- Annual river losses of $23.0 \times 10^6 \text{ m}^3$ and an operating loss component of $11.5 \times 10^6 \text{ m}^3$ are included. These losses were not simulated in the original Operating Rule 1 scenario.
- No operating releases from reservoirs, releases will be demand driven.

3.2 SCENARIO 1

IFRs were assessed for the recommended ERC, the ERC higher than the recommended and one category lower than the recommended ERC. The combination of Upper, Lower and Recommended ERCs are illustrated in Table 3.2.

Sc 1 models the Present Day as described above and supplies the IFRs as a priority at the Upper ERC level.

3.3 SCENARIO 2

This scenario is the same as Sc 1; however all IFRs are supplied at the Recommended ERC level.

3.4 SCENARIO 3

This scenario is the same as Sc 1; however all IFRs are supplied at the ERC lower than the recommended.

3.5 SCENARIO 4

This scenario is modeled using the 2000 Present day as described under 3.1. The scenario is in essence a modification of Sc 2, i.e. all IFRs are supplied for the Recommended ERC with the following changes:

- Use the lowest category (C/D) at IFR site 4.
- Reduce drought flows at IFR site 3, (Little Thukela River) 7 and 8 (Sundays River) by half.
- Reduce maintenance low flows in June, July and August for all sites on the Mooi River (Sites 10, 11 and 12).
- For IFR sites 15 and 16 where scenario requirements exceed Present Day Sc 7 flows, flows were reduced to present day flows.

3.6 SCENARIO 5

This scenario is essentially the same as scenario 4 with the following additional change:

- Remove low assurance high flow (floods) from all sites.

3.7 SCENARIO 6

This scenario is the same as for IFR 5 but all the Reserves (apart from IFR 4 which is still applied at a C/D category) are supplied at the lower ERCs.

3.8 SCENARIO 7

This scenario represents a different version of present day than the present day described under 3.1. The Sc 7 description is similar than the 2000 Present Day, however, the operating releases are now incorporated as in Table 3.1. Operation of the dams will therefore not be demand driven.

Table 3.1 Operating Rule releases for scenario 7

Driel release	2.0m ³ /s
Spioenkop release	2.4m ³ /s
Wagendrift release	2.5m ³ /s
Chelmsford release	0.8m ³ /s

3.9 SCENARIO 8

Sc 8 is a theoretical scenario to serve as a worst-case scenario. It represents 2015 development with NO IFR releases. The characteristics of the 2015 development level is as follows:

- 2015 Development level abstractions and afforestation usage.
- A maximum transfer of 3.2m³/s from Mearns weir, with the proposed Springrove Dam in place. An allowance for an additional transfer from Springrove Dam to Midmar Dam of a maximum of 1.3m³/s, allowing for a total maximum transfer capacity of 4.5m³/s.
- No TWP dams in place.
- 19m³/s being transferred from Driel Barrage, with support from Clifford Chambers weir.
- 1.2m³/s transfer from Middeldrift to the Mhlathuze River catchment.
- Transfer to Fairbreeze Mine of 0.417 m³/s and to Fairbreeze Irrigators of 0.521m³/s, the supply to the irrigators will be supplied from run of river and will not be supported from storage.
- 1m³/s transfer from Zaaihoek Dam to the Vaal River catchment and the Majuba Power Station.
- Annual river losses of 23.0 10⁶m³ and an operating loss component of 11.5 10⁶ m³ are included.
- The releases from the reservoirs will be based on current operating rules and is summarised in Table 3.1.

3.10 SCENARIOS SELECTED FOR ECOLOGICAL CONSEQUENCES EVALUATION

The eight scenarios described were evaluated and it was decided that the following scenarios would not be included for the ecological consequences evaluation:

- Scenario 1: This scenario represented an unrealistic scenario as it focused on ERCs which are higher than those recommended by the ecological specialists and, when one considers the practicalities, would be unlikely to achieve.
- Scenario 4: This scenario is similar than Sc 5. Sc 5 however does not include the large floods as part of the IFR requirement and is therefore a more realistic scenario than Sc 4. As the objective of this phase of the study is to identify and evaluate realistic scenarios, which include considering impact on the yield as well operational constraints, Sc 4 does not warrant further investigation.

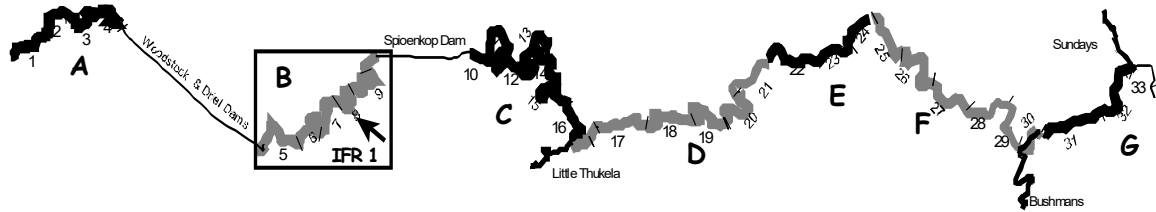
Table 3.2 A combination of Upper, Lower and Recommended ERCs

RU	IFR	Lower Scenario	Recom Scenario	Upper Scenario	Confidence
		ERC	ERC	ERC	
THUKELA RIVER					
A		C/D	B/C	B	Low, extrapolated
B	1	-	D	C	MED-HIGH
C	2	D	C	B	MED-LOW (low flow), MED-High (high flow)
D		D	C	B	Low, extrapolated
E		C	B	-	Low, extrapolated
F	4 *2	B/C	B	-	MED-HIGH
G		D	C/D	B/C	Low, extrapolated
H	9	-	D	C	MED-HIGH*1
I	15	D	C	-	LOW (low flow), MED-HIGH (high flow)
J	16	D	C/D	B/C	MED (low flow), MED-HIGH (high flow)
K			C		
LITTLE THUKELA RIVER					
L	-	D	C	B	Low, extrapolated
M	3	D	C/D	B/C	MED (low flow), MED-HIGH (high flow)
BUSHMANS RIVER					
N		C/D	B/C	B	Low, extrapolated
O	5	C/D	B/C	-	MED (low flow), MED-HIGH (high flow)
P	6	C/D	B/C	-	Low, extrapolated
SUNDAYS RIVER					
Q	7	C/D	B/C	-	MED
R	8	-	D	C	MED-HIGH (low flow), MED (high flow)
MOOI RIVER					
S	10	D	C	B	LOW (drought), MED (high flow)
T	11	C/D	B/C	B	MED-HIGH
BUFFALO RIVER					
U	13	-	D	C	LOW-MED (low flow), MED (>1.8)
V	14	C/D	B/C	-	MED-HIGH

*1 Even though the IFR component evaluation is med-low, flows should be managed from Spioenkop to cater for IFR 4 which is a higher ERC than IFR 9. IFR 9 should therefore get more flows than recommended and the confidence in achieving the ERC is therefore linked to the hydraulics, i.e. med-high.

*2 IFR 4: 3 scenarios were supplied, B (recommended), B/C (alternative and PES), C/D (lower than PES). Only the B and B/C scenario fit into the table and C/D information needs to be used within the design of additional scenarios if necessary.
 C/D, LONG TERM % = 22.6
 MAINTENANCE TOTAL % = 21.8
 % LOW FLOWS = 8.8

4 ECOLOGICAL CONSEQUENCES: IFR 1



4.1 SCENARIOS REQUIRING EVALUATION

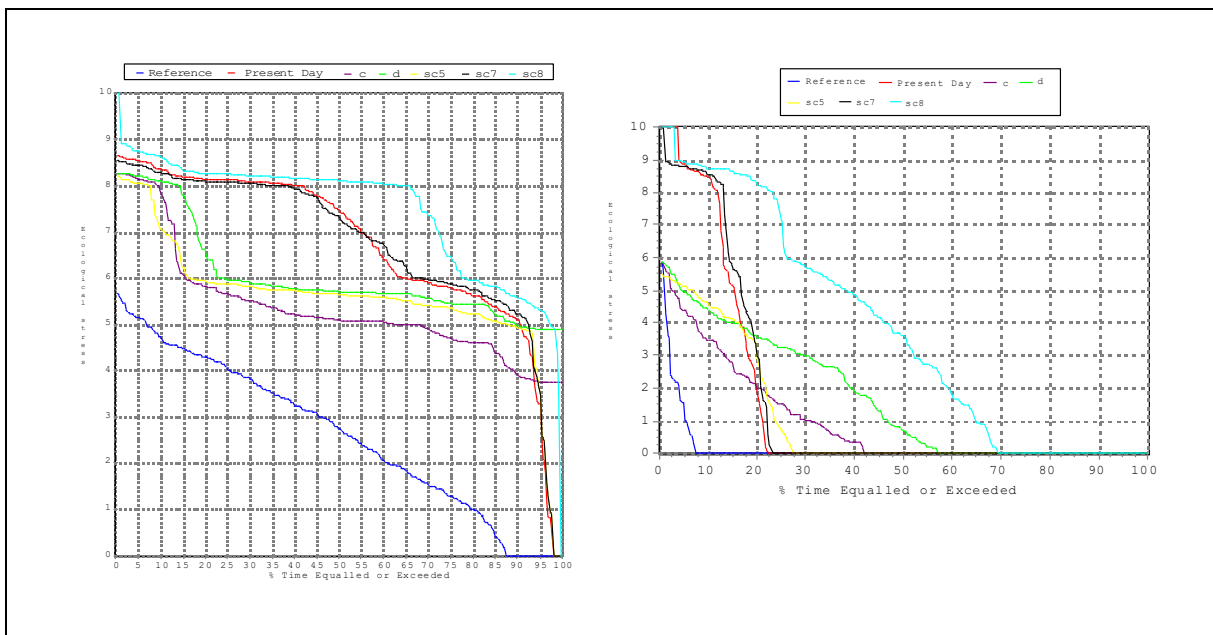
The following scenarios were found to be similar and therefore only Sc 5, 7 and 8 were evaluated.

Note:
Sc 2 = Sc 3 = Sc 5 = Sc 6

4.2 SCENARIOS CONVERTED TO STRESS PROFILES

The scenario was converted to stress and the resulting ECs determined and categories are provided. The graphs illustrating the stress profiles for the wet and dry season are provided below.

Fig 4.1 Dry (left) and wet (right) season stress profiles




4.3 RESULTING ECs FOR EACH SCENARIO

The resulting EC for each component and for the Ecostatus is provided in Figure 4.2. The PES, long-term resulting trajectory EC and ERC are also provided for reference purposes. This information was determined during a previous phase in the project and is provided in DWAF, 2003b (DWAF Report No. PBV000-00-10303).

The motivation for each component EC is provided in the sections below.

Fig 4.2 Resulting component status and Ecostatus

COMPONENT	PES	LONG TERM (20 Y)	ERC	Sc 5	Sc 7	Sc 8
WATER QUALITY	B/C	B/C	B/C	B/C	B/C	C
GEOMORPH	D	D/E	D	C	C/D	D
RIPARIAN VEGETATION	E	E/F	D	D	D	E
FISH	D	D	D	C/D	D	E/F
AQUATIC INVERTS	D	D	D	C	E	E
ECOSTATUS	D	E	D	 C/D	D	E

4.4 Sc 5 CONSEQUENCES

Water quality (B/C)

All flow scenarios will satisfy the WQ ERC for inorganic salts and TIN. The SRP will have to be improved, through management practices, from a C (according to the revised methods of DWAF, 2002) to B/C category.

Geomorphology (C)

There is improved geomorphology as a result of managed floods, as per the IFR requirements. A qualitative assessment of wet season hydrology indicates higher flows than requested for the IFR. These flows approximate present day flows (volume), but there is an assumption that the available volume is managed to produce requested flood peaks. These floods have geomorphological significance for the Scouring of sediments.

Riparian Vegetation (All components) (D)

Vegetation requirements are not critical, and all the flow scenarios are therefore higher than required for the vegetation. The vegetation category will therefore remain a D.

Fish (C/D)

The category allocated is a C/D. This will allow for the maintenance of moderate populations of adult *Labeo natalensis* in pools and shallows, and will limit the impact of suspended silt from Driel Barrage, scour releases on fish respiration and the abundance of macro-invertebrate food organisms. During the dry season, drought decreases but flow is adequate for *Amphilius* sp.

Aquatic Invertebrates (C)

Dry Season: For the bulk of the dry season, Sc 5 will be in a category D, but during high stress times (stress > 6), the scenario moves the category up to a C. As this is the critical period of the year, this means that Sc 5 in winter is a category C. Under Sc 5, high stresses of 6 - 8.5 will occur less frequently, enabling rheophilic species to survive with great assurance.

Wet Season: Marginal vegetation invertebrates are the critical component, as marginal vegetation needs to be inundated to supply habitat during summer (which equates to a low stress condition). Low stress in summer is important and is supplied better than the D category (ERC), and is even better than a C category at stresses <2.

Ecostatus (C/D)

The important driver in this case is geomorphology and hydrology. As the flow scenarios improved as well as geomorphology, there has to be an increase in category, i.e. from the D ERC to a C/D EC. It must be noted that uncertainty existed whether this scenario would represent a C or C/D EC.

4.5 Sc 7 CONSEQUENCES**Water quality (B/C)**

All flow scenarios will satisfy the water quality ERC for inorganic salts and TIN. The SRP will have to be improved, through management practices, from a C (according to the revised methods of DWAF, 2002) to a B/C category.

Geomorphology (C/D)

This change in ERC assumes an improved management of excess water to supply *some* flood peaks and therefore create some scouring. This is still a better situation than the ERC, although not the same as for Sc 5.

Riparian Vegetation (D)

Vegetation requirements are not critical, and all the flow scenarios are therefore higher than required for the vegetation. The vegetation category will therefore remain a D.

Wet and dry season, critical stress: The vigour of existing *Setaria* clumps is likely to be maintained due to sufficient periods during which stress exceeds 8 (i.e. not exceeding 5% of the time). This site is therefore likely to remain in its existing category.

Fish (D)

Wet and dry season: Similar to Present Day, i.e. a D category, with the same motivations.

Aquatic Invertebrates (E)

Dry Season: For the bulk of the time, stress (between 6 and 8) is greater than required for a D category, which will push the invertebrates into an E category. The reason for this is that flow-dependent species will have less chance of survival.

Wet Season: During drought conditions, stress levels are greater than required for a D category. This will however not be enough to push the invertebrates into a lower category, as most of these species will survive on alternative substrates.

Ecostatus (D)

All the categories are the same as for the ERC apart from geomorphology that is a half a category better than the ERC and aquatic invertebrates which is a category worse than the ERC. It was decided that this balanced each other and the same Ecostatus category as the ERC that was selected.

4.6 Sc 8 CONSEQUENCES

Water quality (C)

If improved management practices are not implemented, the overall water quality status will move from a B/C to C category for scenario 8, under the revised methods of DWAF, 2002, and B to B/C for scenario 8, under the methods of DWAF, 1999 (due to the elevated SRP levels). The revised methods (DWAF, 2002) therefore drops the PES a half a category.

Geomorphology (D)

The flows are similar as required for the geomorphology ERC and the resulting category is therefore the same.

Riparian Vegetation (E)

Scenario 8 is likely to drop a category due to the reduction and loss of new recruitment of *Setaria* in marginal areas and on islands. *Juncus* is likely to be unaffected by Sc 7 and 8.

The flowering of the Fire Lily is likely to be reduced due to high stress levels exceeding that of the recommended ERC, however this is unlikely to drop a category.

Setaria sp.

Wet season, critical stress: Extended (i.e. >30% of the time) levels of stress above 8.8 are likely to lead to a loss of recruitment of additional *Setaria* clumps in marginal areas and islands. The change in category is due to this reduced recruitment.

Fish (E/F)

Dry season: The rationale for the E/F category is that in Sc 8, drought durations are extended during the wet and the dry seasons, *Amphilius* sp. is likely to be lost, and there is likely to be a high mortality of *Labeobarbus* sp.

Aquatic Invertebrates (E)

Dry Season: Moderate stress levels (6 - 8) will occur at much higher frequency than Sc 7, resulting in a lowering of the category due to a loss of rheophilic species.

Wet Season: Stresses of >7 are frequent enough to reduce the category. Stresses of >7 for 25% of summer are unacceptable as marginal vegetation habitat will not be available during these periods.















Ecostatus (E)

All the categories apart from water quality and geomorphology are in an unacceptable EC, i.e. below a D. The resulting EC is an E, i.e. worse than the ERC.

4.7 COMPARISON OF SCENARIOS

A comparison of the scenarios is illustrated in Table 4.1 below.

Table 4.1 Comparison of the ecological consequences of scenarios – IFR 1

Sc	Category	Worse				Same				Improved		
2,3,5,6 ↑	C/D											
7 ↔	D											
8 ↓	E											

4.8 CONSIDERATION OF NON-FLOW RELATED ISSUES

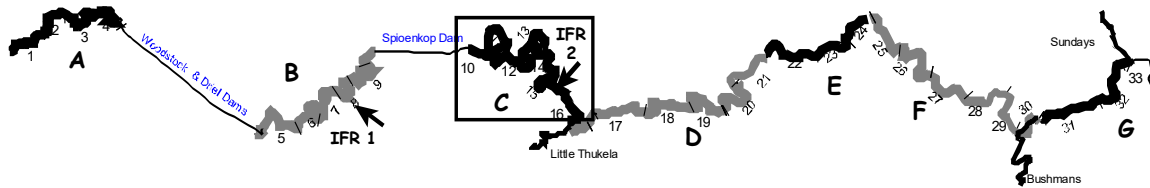
Riparian vegetation

Increased flows are likely to widen the marginal zone. However, due to the presence of alien species – it is unlikely to improve further to a D category in scenarios 2, 3, 5 and 6.

Ecstatus

Taking into account possible poor water quality from the abattoir, as well as scouring of the Driel Barrage, this could lower the Ecstatus to a D for Sc 2, 3, 5 and 6.

5 ECOLOGICAL CONSEQUENCES: IFR 2



5.1 SCENARIOS REQUIRING EVALUATION

The following scenarios were found to be similar and therefore only Sc 3, 6, 7 and 8 were evaluated.

Note:
 Sc 2 = Sc 3
 Sc 5 = Sc 6

5.2 SCENARIOS CONVERTED TO STRESS PROFILES

Fig 5.1 Dry season stress profiles

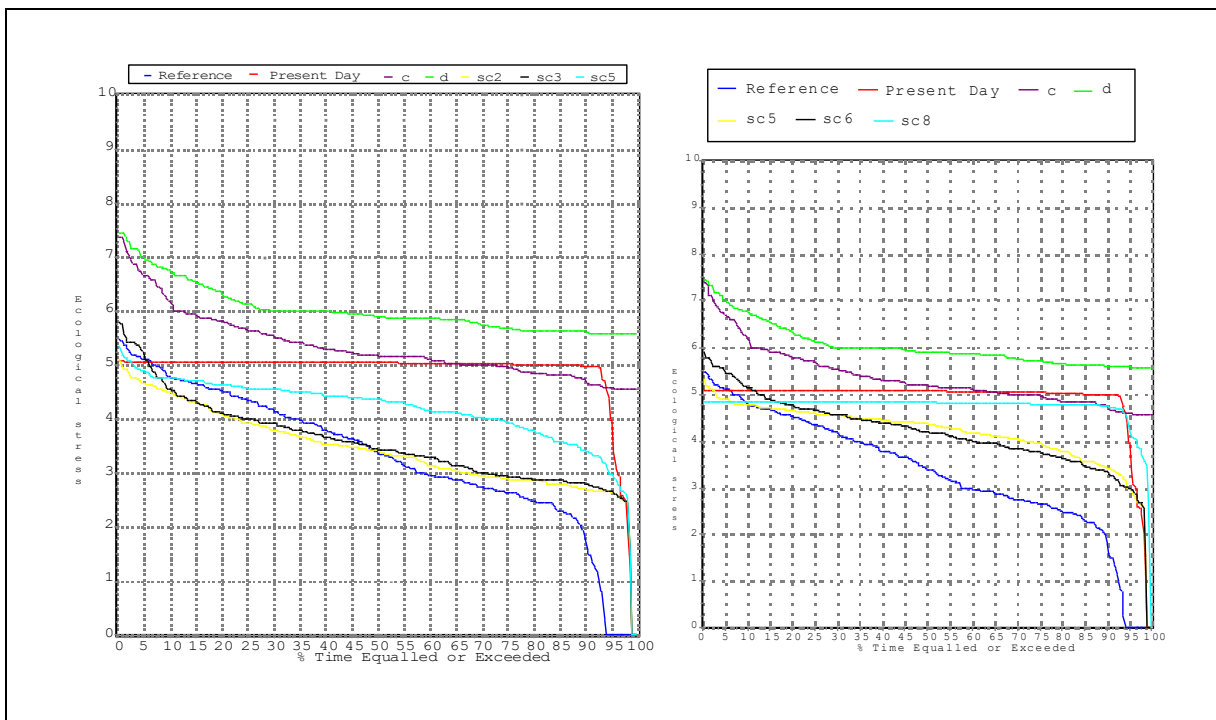
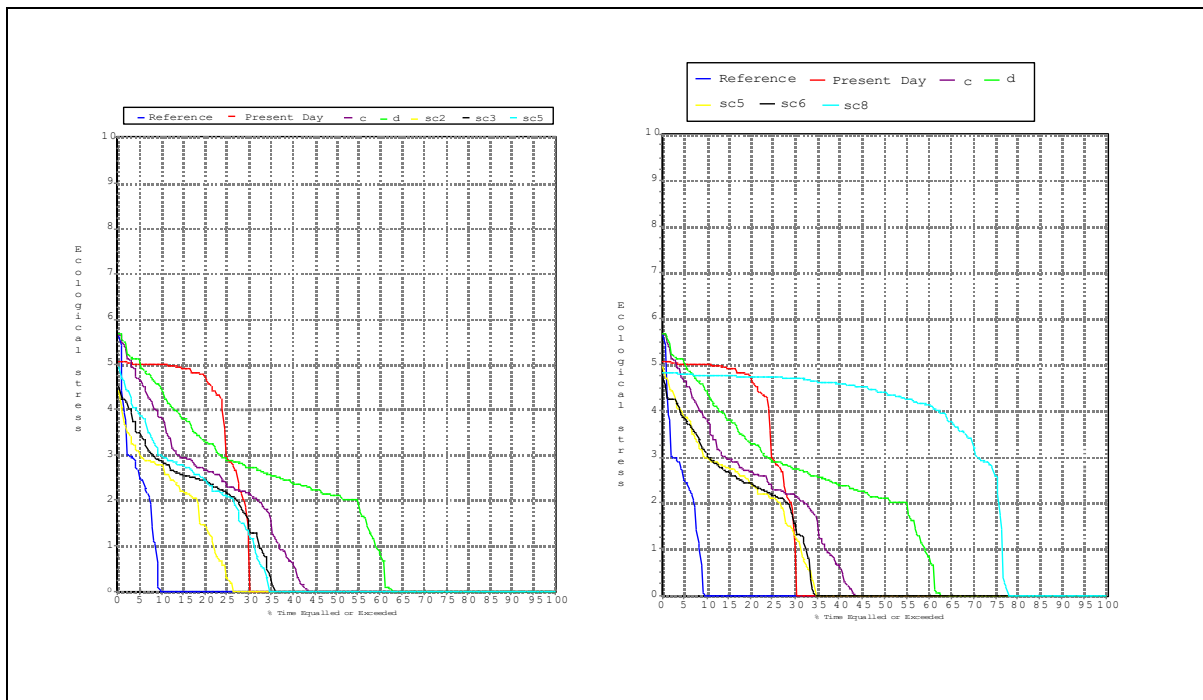


Fig 5.2 Wet season stress profiles



5.3 RESULTING ECs FOR EACH SCENARIO

The resulting EC for each component and for the Ecostatus is provided in the Figure 5.2. The PES, long-term resulting trajectory and ERC are also provided for reference purposes. This information was determined during a previous phase in the project and is provided in DWAF, 2003b (DWAF Report No. PBV000-00-10303).

The motivation for each component category is provided in the sections below.

Fig 5.3 Resulting component status and Ecostatus

COMPONENT	PES	LONG TERM (20 Y)	ERC	DOWN	Sc 2	Sc 6	Sc 7	Sc 8
WATER QUALITY	B	B	B		A/B	B	B	B
GEOMORPH	D	D/E	D	D	C	C	C	D/E
RIPARIAN VEGETATION	C	C/D	C	D	B/C	B/C	C	D
FISH	C	C	C	D	B	B/C	C	D
AQUATIC INVERTS	B/C	C/D	B/C	C/D	B	B	B/C	B/C
ECOSTATUS	C	C	C	D	B	B/C	C	D

5.4 Sc 2 CONSEQUENCES

Water quality (A/B)

Under Sc 2 and 3, SRP and TIN are expected to improve, thereby resulting in an A/B category.

Geomorphology (C)

The category improves to a C as a result of more water than recommended for the IFR.

Riparian Vegetation (B/C)

Existing mixed clumps of *Setaria* and mats of *Juncus* will remain in tact. Additional water/reduced stress will probably lead to increased recruitment and the extension of the marginal zone on islands and in marginal areas. Existing adults of *Salix* are likely to be maintained on islands and in marginal areas. This will lead to the extension of *Salix* in higher-lying areas. Additional water, leading to reduced stress, is likely to encourage germination and growth in higher marginal areas and islands and the category is therefore likely to improve to a B/C.

Fish (B)

Dry season: This scenario is close to natural conditions but with less stress. Close to optimum habitat conditions for *Amphilius*.

Aquatic Invertebrates (B)

Current excessive and constant flows during winter will be improved by introducing some variability. During summer greater flows than present will improve the inundation of marginal vegetation and thus habitat for invertebrates. The category can be expected to improve to a Category B.

Ecostatus (B)

All components have increased in category, two by half a category and three by a category. It was therefore felt that the system would improve from a C to a D category.

5.5 Sc 6 CONSEQUENCES**Water quality (B)**

Scenarios 5 (+6) and 7 (+8) will all result in a B category for water quality, as conditions are mostly similar to present EC. Overall water quality status will therefore stay the same.

Geomorphology (C)

See Sc 2.

Riparian Vegetation (B/C)

See Sc 2.

Fish (B/C)

Dry season: The stress is higher than natural conditions (>2) and an impact on habitat availability would be expected at this particular site.

Aquatic Invertebrates (B)

Dry season: There will be some improvement in the flow compared to present day conditions, as a result of introducing some variability. However, the category remains the same.

Wet season: Greater flows than present day conditions will improve the inundation of the marginal vegetation and thus the habitat for invertebrates.

Ecostatus (B/C)

Three components have increased by half a category, one by a full category and one has remained the same. This implies that the Ecostatus should be half a category higher than the ERC, i.e. higher than the ERC, but lower than scenario 2. The resulting EC is therefore a B/C.

5.6 Sc 7 CONSEQUENCES**Water quality (B)**

See Sc 5.

Geomorphology (C)

See Sc 2.

Riparian Vegetation (C)

This scenario will result in the maintenance of existing marginal areas and the cover of *Setaria/Juncus* as well as *Salix*, and therefore likely to remain a C ERC.

Fish (C)

The scenario is similar to the ERC flows, and therefore there is no change in category.

Aquatic Invertebrates (B/C)

Dry season: Most of the impacts at this site are flow-related, so the Sc7 can be considered the same as for present day.

Wet season: Although the critical stress is high for >20% of the time, the stress for invertebrates is lower (3 - 4) and thus the impacts on invertebrates will be less. The habitat will remain adequate.

Ecostatus (C)

All components are the same as for the ERC, apart from geomorphology, which is a category higher. The resulting category is therefore the same as for the ERC.

5.7 Sc 8 CONSEQUENCES**Water quality (B)**

See Sc 7.

Geomorphology (D/E)

This scenario illustrates less flow than requested and assumes that this means floods are lost, causing degradation (through sediment deposition).

Riparian Vegetation (D)

Stress levels of *Setaria* and *Juncus* mixed adults are unlikely to reach high enough levels to reduce or lead to a reduction in the number of existing clumps, and therefore likely to remain at C ERC. However, when the reduced high flows are also considered, this may decrease to a D. This is due to the fact that the maintenance of the marginal zone by high flows will not be possible, leading to narrowing of the marginal zone, and loss of recruitment of all species.

Fish (D)

Wet season: A stress of more than 4 occurs far more often in this scenario. Lower habitat abundance and lower abundance of *Amphilius* is expected, and the breeding season in particular will be impacted. This will lead to a lower category, i.e. a D.

Aquatic Invertebrates (B/C)

Dry season: This scenario is essentially the same as present day.

Wet season: Although the critical stress is >3 for 70% of the time, the stress for invertebrates will be zero, thus not altering the category (as marginal vegetation will be well inundated).





















Ecostatus (D)

Three of the five components are lower than the ERC which results in a lower category than the ERC, i.e. a D category.

5.8 COMPARISON OF SCENARIOS

A comparison of the scenarios is illustrated in Table 5.1 below.

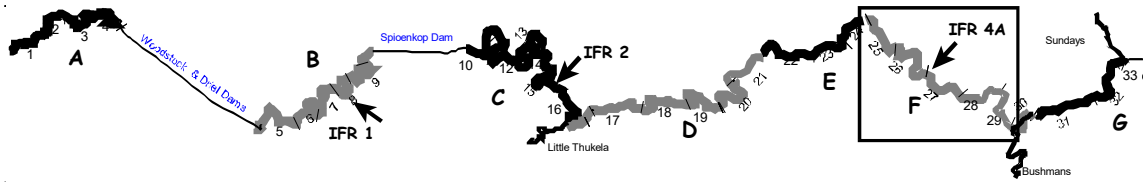
Table 5.1 Comparison of the ecological consequences of scenarios – IFR 2

Sc	Category	Worse			Same				Improved				
2, 3 ↑	B												
5, 6 ↑	B/C												
7 ↔	C												
8 ↓	D												

5.9 CONSIDERATION OF NON-FLOW RELATED ISSUES

Due to grazing the vegetation will probably drop half a class but that will not impact on the Ecstatus.

6 ECOLOGICAL CONSEQUENCES: IFR 4



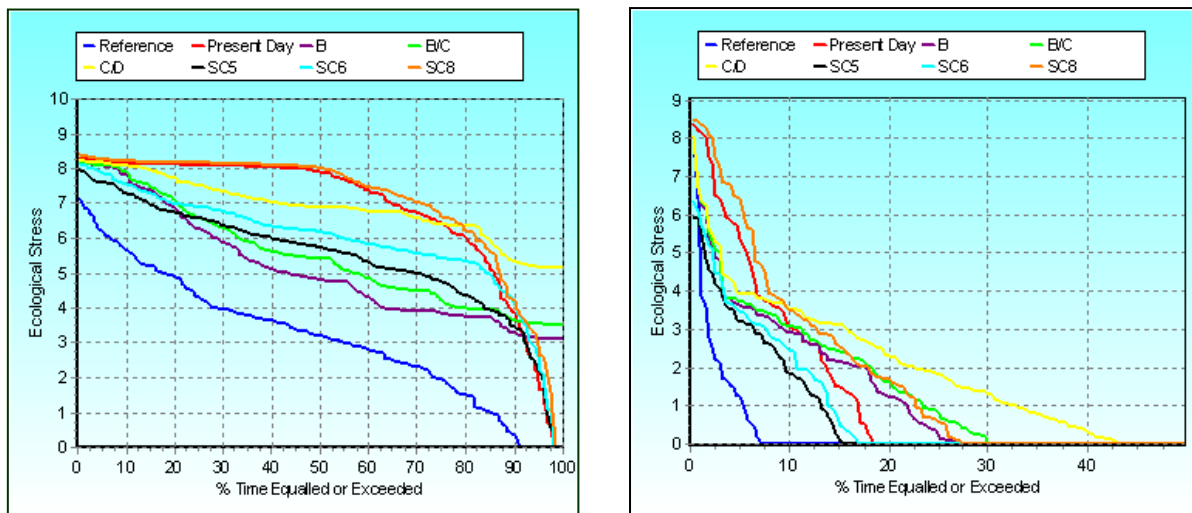
6.1 SCENARIOS REQUIRING EVALUATION

The following scenarios were found to be similar and therefore only Sc 3, 6, 7 and 8 were evaluated.

Note:
 Sc 2 = Sc 3
 Sc 5 = Sc 6

6.2 SCENARIOS CONVERTED TO STRESS PROFILES

Fig 6.1 Dry (left) and wet (right) season stress profiles



6.3 RESULTING ECs FOR EACH SCENARIO

The resulting EC for each component and for the Ecostatus is provided in Figure 6.2. The PES, long-term resulting trajectory and ERC are also provided for reference purposes. This information was determined during a previous phase in the project and is provided in DWAF, 2003b (DWAF Report No. PBV000-00-10303).

The motivation for each component EC is provided in the sections below.

Fig 6.2 Resulting component status and Ecostatus

COMPONENT	PES Sc3IFR	LONG TERM (20 Y)	ERC Sc2IFR	DOWN	Sc 3	Sc 6	Sc 7	Sc 8
WATER QUALITY	C	C	C		C	C	C	C/D
GEOMORPH	B/C	B/C	B/C	C/D	B/C	B/C	B/C	B/C
RIPARIAN VEGETATION	C	C/D	C	D	B/C	B/C	C	C/D
FISH	B*1?	B?	B?	C?	B/C	C/D	E/F	E/F
AQUATIC INVERTS	B/C	B/C	B	C/D	B	B/C	C/D	D
ECOSTATUS	B/C	B/C	B	C/D	B/C	B/C	D	D

*1 Uncertainty was expressed at this specialist meeting regarding the previously assessed fish categories. The fish scenario evaluation is therefore not the same as previous determined ERCs.

6.4 SC 3 CONSEQUENCES

Water quality (C)

For scenario 3, it is possible that the WQ category may improve to a B/C as flows are higher in the dry season, but as there is minimal data, no modeling information, and no data for the wet season (data collected in August and September 2001), it will be assumed that conditions will not improve enough to change category.

Geomorphology (B/C)

As with the previous sites, flows are higher than requested for the IFR and are very similar to present day flows. The category remains a B/C for all scenarios because problems at this site are non-flow-related. The site is also very resilient and geomorphologically stable.

Riparian Vegetation (B/C)

The Scenario is likely to result in an improvement in category. This is due to the increased availability of water and the maintenance of existing clumps of *Setaria/Juncus*, as well as improved recruitment and extension of the marginal zone. This will result in a significant improvement in the density of *Setaria/Juncus* but with reduced resilience and an improvement in category.

Dry season, critical stress of 5: Existing clumps of *Setaria* adults will be maintained, thus the existing category will be maintained or improved.

Dry season, critical stress of 8: Insufficient death of older *Setaria* clumps leads to reduced long-term vigour and resilience. The existing category will therefore be maintained.

Wet season, critical stress: Most of existing clumps of *Setaria* will be maintained because stresses of <5 occur for >95% of the time, therefore the category is likely to increase or be

maintained. This will also encourage improvement in the width and extent of the marginal zone.

Setaria juveniles

Dry season, critical stress: Significantly reduced stresses and increased resilience leads to a tempering² function and therefore the category is maintained.

Wet season, critical stress: There is sufficient water is likely to be present to ensure healthy recruitment of *Setaria* seedlings in marginal areas during autumn and early winter (duration >70%). This is likely to lead to an increase in marginal areas. There is an increase or maintenance of the category.

Fish (B/C)

Dry season: The stress is below 8 and only falls between 7 – 8 for 10% of the time. The conditions are adequate for the survival of *Amphilius* and *Labeobarbus* spp.

Wet season: There is more than enough habitat for the spawning success of the two species under consideration.

Aquatic invertebrates (B)

Dry season: This scenario resembles the B category above having stress levels of 4.8 for approximately 30% of the time. Habitat quality would be good.

Wet season: Sc 3 will have less stress than natural conditions during wet droughts. This will have some negative impacts. Otherwise, invertebrates are equal to or better than a B/C category, and therefore categorized as a B.

Ecostatus (B/C)

The geomorphology driver is in a B/C category as well as all riparian vegetation and fish. Aquatic invertebrates category is a B and water quality a C. The most likely Ecostatus would therefore follow the geomorphology driver and the majority of categories, i.e. a B/C.

6.5 Sc 6 CONSEQUENCES

Water quality (C)

For scenarios 6 and 7, flows are similar to present, and there is insufficient data to suggest a change from present EC for water quality.

Geomorphology (B/C)

The same as for Sc 3.

Riparian Vegetation (B/C)

The same as for Sc 3.

Fish (C/D)

There is a stress of 7 – 8 for 20% of the time. There will be some mortality of *Amphilius*, lowered abundances of *Labeobarbus* sp., a lack of suitable habitat, lowered oxygen concentrations, and raised water temperatures.

Aquatic Invertebrates (B/C)

Dry season: This scenario is similar to the B/C graph and satisfies the ecological conditions described by a B/C.

Wet season: Sc 5/6 is similar to the B/C recommendations, including the drought wet seasons as found under natural conditions.

²

It is the process whereby the resilience of the system is gradually built up in response to a specific flow regime. In the case of resilience to flooding (for example) this entails the gradual recovery of a marginal zone (in the short absence of frequent excessive floods). The zone subsequently widens and is colonised by species such as *Salix mucronata*, which slowly stabilise this newly established marginal zone. Eventually it will become quite persistent to the point that the site will be able to reestablish itself much faster and more effectively after floods i.e., it now has resilience to floods.

Ecostatus (B/C)

The difference between scenario 6 and 3 is that the fish are in a lower (than B/C) category and the aquatic invertebrates are a B/C instead of a B. The most likely Ecostatus would therefore follow the geomorphology driver and the majority of categories, i.e. a B/C. Sc 6 would probably be closer to a C than scenario 3.

6.6 Sc 7 CONSEQUENCES**Water quality (C)**

See Sc 6.

Geomorphology (B/C)

See Sc 3.

Riparian Vegetation (C)

Existing *Setaria* clumps will be maintained, due to lower stress. This is likely to result in the maintenance of the existing C category.

Setaria adults

Dry season, critical stress of 5: Extended duration (> 50%) of stress values > 8. This will lead to death and thinning of mixed clumps of *Setaria* and *Juncus* during winter months.

Dry season, critical stress of 8: Extended duration (> 50%) of stress values >7.9. This will lead to the excessive death of older *Setaria* clumps during drought and some winter months. While this encourages improved vigour of remaining individuals during drought conditions, this situation may lead to significant reductions in clumps in the marginal areas with an expected decrease in category.

Wet Season, critical stress: Most of existing clumps of *Setaria/Juncus* will remain because stresses of <5 occur for > 95% of the time. The category is therefore likely to be maintained or improved.

Setaria juveniles

Dry season, critical stress of 5: Limited stresses in excess of 8.4. Therefore, limited resilience tempering of *Setaria* population due to limited reduction in seedling germination during the dry season. This could result in reduced development of resilience in the *Setaria* population. Thus scenario is likely to maintain the existing category.

Wet season, critical stress of 8: Sufficient water to ensure healthy recruitment of *Setaria* seedlings in marginal areas during autumn and early winter. (Duration > 70%). This is likely to lead to an increase in marginal recruitment with an improvement or maintenance of the category.

Fish (E/F)

High mortalities of both *Amphilius* and *Labeobarbus* will occur, with *Amphilius* probably extinct. Habitat (flowing) is absent.

Aquatic Invertebrates (C/D)

Dry season: For > 20% of the time, stress is greater than a C/D category, which means that in winter many rheophilic species will be seriously threatened.

Wet season: During wet season flows stress is low, but for <10% of the time, the stress is greater than B/C and significantly worse than natural conditions.

Ecostatus (D)

The geomorphology driver is still in a B/C category. However, compared to Sc 6, the riparian vegetation has fallen by half a category, fish has fallen by a full category into an unacceptable EC and aquatic invertebrates by a full category. It was therefore deemed that the Ecostatus would be lower, either a C/D or a D. Comparing the stress profiles of the C/D IFR to the profile of Sc 7, it became obvious that the Ecostatus must be a D due to the fact that Sc 7 is considerably worse than the C/D IFR.

6.7 Sc 8 CONSEQUENCES

Water quality (C/D)

Conditions are expected to deteriorate under scenario 8 as flows are reduced during the wet season, and a category change to a C/D category is predicted (conservative approach due to lack of data).

Geomorphology (B/C)

See Sc 3.

Riparian Vegetation (C/D)

Existing *Setaria* clumps are likely to remain due to lower stress. The extended duration of stress could lead to losses in density and recruitment of clumps.

Setaria adults

Dry season, critical stress of 5: Extended duration (> 50%) of stress values > 8. This will lead to death and thinning of mixed clumps of *Setaria* and *Juncus* during winter months.

Dry season, critical stress of 8: Extended duration (> 50%) of stress values >7.9. This will lead to excessive death of older *Setaria* clumps during drought and general winter months. While this encourages improved vigour of remaining individuals during drought conditions, this situation may lead to significant reductions in marginal zone clumps, with an expected decrease in category.

Wet Season: Most of existing clumps of *Setaria/Juncus* will be maintained because stresses of <5 occur for > 95% of the time. The category is thus maintained or increased.

Setaria juveniles

Dry season, critical stress: Limited stresses in excess of 8.4. Therefore, limited resilience tempering of *Setaria* population as a result of limited reductions in seedling germination. This results in reduced development of resilience with the maintenance of the category.

Wet season, critical stress: There is sufficient water to ensure healthy recruitment of *Setaria* seedlings in marginal areas during autumn and early winter. (Duration > 70%). This will lead to a possible increase in marginal recruitment. Therefore, increase or maintain the category.

Fish (E/F)

See Sc 7.

Aquatic Invertebrates (D)

Dry season: For > 20% of the time, the stress is greater than a C/D category, which means that in winter many rheophilic species will be seriously threatened.

Wet season: For < 5% of the year, stress becomes excessive (> 6.5), where marginal vegetation is no longer a habitat for invertebrates.





















Ecostatus (D)

The geomorphology driver is still in a B/C category. However, compared to Sc 7, both riparian vegetation and aquatic invertebrates have declined further. This Ecostatus is therefore most likely to be in a D category, especially when comparing the stress profiles and the similarity with the Sc 7 stress profile.

6.8 COMPARISON OF SCENARIOS

A comparison of the scenarios is illustrated in Table 6.1 below.

Table 6.1 Comparison of the ecological consequences of scenarios – IFR 4

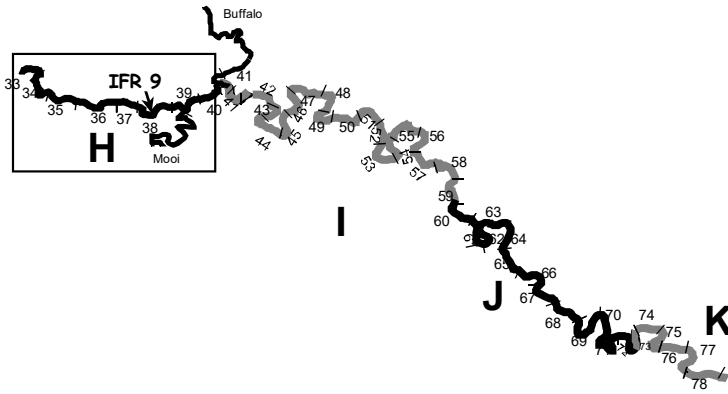
Sc	EC	Worse				Same			Improved
2,3 ↓	B/C								
5, 6 ↓	B/C								
7 ↓	D								
8 ↓	D								

6.9 CONSIDERATION OF NON-FLOW RELATED ISSUES

If one takes the non-flow related issues into account, the water quality Reserve category is not likely to be met under Sc 8. Source-directed controls, particularly on the Klip River system, would have to be implemented to improve conditions to attain required water quality category under this scenario.

No other changes in the component categories are expected and the overall Ecstatus for the relative scenarios will stay the same.

7 ECOLOGICAL CONSEQUENCES: IFR 9



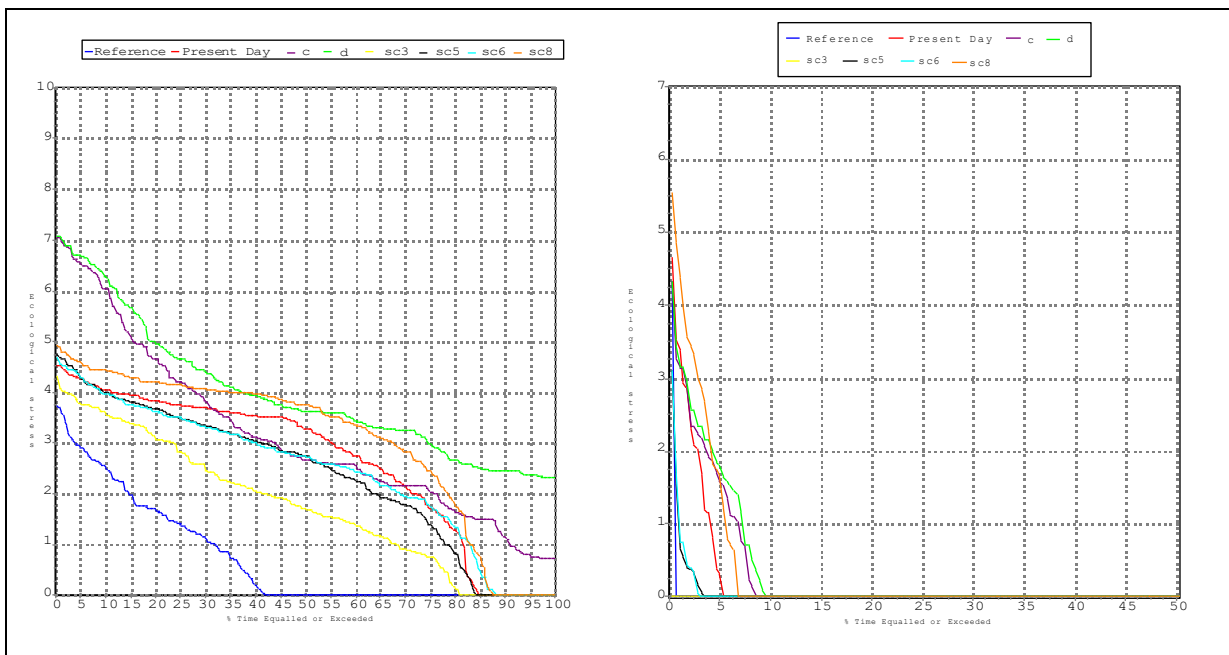
7.1 SCENARIOS REQUIRING EVALUATION

The following scenarios were found to be similar and therefore only Sc 2, 6 and 8 were evaluated.

Note:
Sc 2 = Sc 3
Sc 5 = Sc 6
Sc 7 = Sc 8

7.2 SCENARIOS CONVERTED TO STRESS PROFILES

Fig 7.1 Dry (left) and wet (right) season stress profiles






7.3 RESULTING ECs FOR EACH SCENARIO

The resulting EC for each component and for the Ecostatus is provided in Figure 7.2. The PES, long-term resulting trajectory and ERC are also provided for reference purposes. This information was determined during a previous phase in the project and is provided in DWAF, 2003b (DWAF Report No. PBV000-00-10303).

The motivation for each component EC is provided in the sections below.

Fig 7.2 Resulting component status and Ecostatus

COMPONENT	PES	LONG TERM (20 Y)	ERC	Sc 2	Sc 6	Sc 8
WATER QUALITY	B/C	C	B/C	B/C	B/C	B/C
GEOMORPH	D	D/E	D	D	D	D
RIPARIAN VEGETATION	E	E/F	D	C	C	D
FISH	B	C	B	B	C	C/D
AQUATIC INVERTS	C	C	C	A/B	A/B	B/C
ECOSTATUS	D	D/E	D	 C	 C	 C/D

7.4 Sc 2 CONSEQUENCES

Water quality (B/C)

Water quality is in a B/C category, for all the scenarios, under the revised methods of DWAF (2002), meaning that the water quality reserve of a B/C category will be met under all scenarios.

Geomorphology (D)

All scenarios illustrate a higher flow than that requested for the IFR. This flow volume approximates present day flows. The category cannot be improved at this site using flow.

Riparian Vegetation (C)

Very limited and no suitable vegetation is present at this site, and consequently there are also no stress curves to deal with. The assessment of scenarios is based on a theoretical understanding of the status and condition of the vegetation if present. No ecological details or motivations are possible, just an estimate of conditions based on flow scenarios.

Fish (B)

Dry season: There is a slight loss of suitable habitat, but the scenario still meets all habitat requirements of *Amphilius* and *Labeobarbus*. The stress is low at <4.

Aquatic Invertebrates (A/B)

Dry season: Stress levels are very low (<4) for 100% of the time. The habitat will thus remain abundant.

Wet season: The stress is negligible and optimum habitat is available.

Ecostatus (C)

Riparian vegetation and aquatic invertebrates have improved from the ERCs. It was therefore felt that the Ecostatus warranted improvement by a category, especially considering that aquatic invertebrates improved from a C to an A/B category. The stress profile of Sc 3 is considerably better (dry season) than the C IFR curve. It was however felt to still keep within the C band.

7.5 Sc 6 CONSEQUENCES**Water quality (B/C)**

See Sc 2.

Geomorphology (D)

See Sc 2.

Riparian Vegetation (C)

See Sc 2.

Fish (C)

As for Sc2, but slightly more loss of habitat in the dry season, with stresses of 4 - 5.

Aquatic Invertebrates (A/B)

See Sc 2.

Ecostatus (C)

Riparian Vegetation and aquatic invertebrates have improved from the ERCs. It was therefore felt that the Ecostatus warranted improvement by a category, especially considering that aquatic invertebrates improved from a C to an A/B category. The stress profile of Sc 5 lies between the C IFR and D profiles; however it was felt to still keep within the lower section of the C band.

7.6 Sc 8 CONSEQUENCES**Water quality (B/C)**

See Sc 2.

Geomorphology (D)

See Sc 2.

Riparian Vegetation (D)

See Sc 2.

Fish (C/D)

A loss of suitable habitat occurs, similar to the previous scenarios, but for an extended period, with stresses of 4 - 5 for 35% of the time.

Aquatic Invertebrates (B/C)

Dry season: Although high stress levels warrant a B category, for much of the year stress will remain in the 3 - 4 band, thus reducing the category.

Wet season: Stress reaches a maximum for very short periods of time (<3%), so habitats remain good.

Note: No vegetation was present, but if it had been, categories would have been the same as for the flow dependent invertebrates.



















Ecostatus (C/D)

Compared to Sc 6, riparian vegetation, fish, and aquatic invertebrates have not dropped categories. The Ecostatus must therefore be lower than a C and was set as a C/D.

7.7 COMPARISON OF SCENARIOS

A comparison of the scenarios is illustrated in Table 7.1 below.

Table 7.1 Comparison of the ecological consequences of scenarios – IFR 9

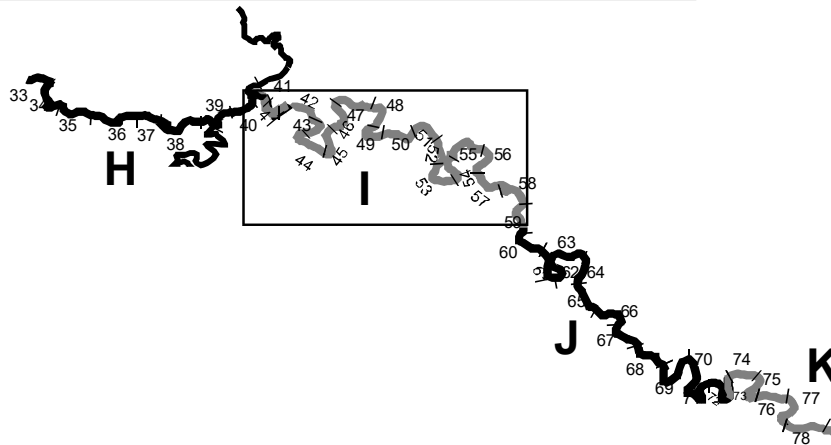
Sc	EC	Worse	Same				Improved	
2,3 	C							
5, 6 	C							
7, 8 	C/D							

7.8 CONSIDERATION OF NON-FLOW RELATED ISSUES

If non-flow related actions were taken into account with riparian vegetation in mind, the vegetation would be an E under all the scenarios. Aquatic invertebrates would drop categories on the basis of non-flow related problems.

With riparian vegetation being an E under all circumstances as well as aquatic invertebrates and water quality being lower, it can be assumed that the Ecstatus will be lower. However, it will probably not fall below a D and therefore the only change will be that the recommended ERC has been achieved, but not improved.

8 ECOLOGICAL CONSEQUENCES: IFR 15



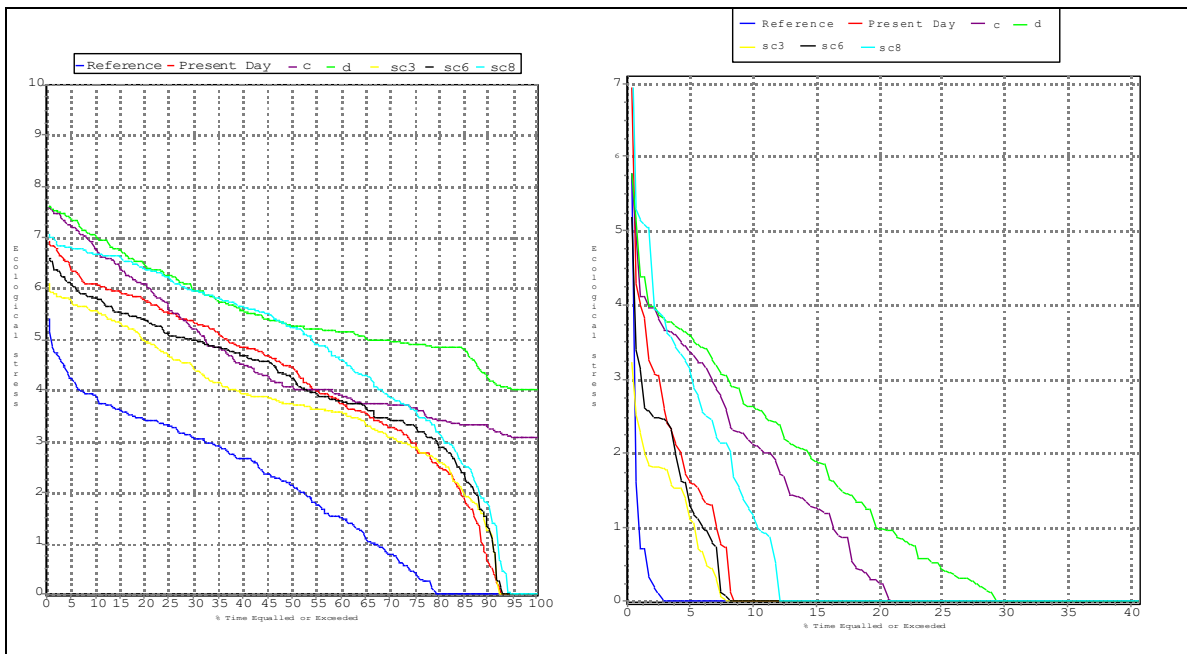
8.1 SCENARIOS REQUIRING EVALUATION

The following scenarios were found to be similar and therefore only Sc 3, 6 and 8 were evaluated.

Note:
Sc 2 = Sc 3
Sc 5 = Sc 6
Sc 7 = Sc 8

8.2 SCENARIOS CONVERTED TO STRESS PROFILES

Fig 8.1 Dry (left) and wet (right) season stress profiles



8.3 RESULTING ECS FOR EACH SCENARIO

The resulting EC for each component and for the Ecostatus is provided in Figure 8.2. The PES, long-term resulting trajectory and ERC are also provided for reference purposes. This information was determined during a previous phase in the project and is provided in DWAF, 2003b (DWAF Report No. PBV000-00-10303).

The motivation for each component EC is provided in the sections below.

Fig 8.2 Resulting component status and Ecostatus

COMPONENT	PES	LONG TERM (20 Y)	ERC	DOWN	Sc 3	Sc 6	Sc 8
WATER QUALITY	B/C	C	B/C		B/C	B/C	B/C
GEOMORPH	D	D/E	D	D	D	D	D
RIP VEG (gorge)	C	C	C	D	B/C	B/C	C
RIP VEG (rest)	E	E/F	D	D	C	C	D
FISH	C	C	C	D	B/C	C	C/D
AQUATIC INVERTS	B	B	B	C	B	B	C
ECOSTATUS	C	C/D	C	D	C	C	C/D

8.4 Sc 3 CONSEQUENCES

Water quality (B/C)

No water quality modelling was carried out at this site, as there is no nearby monitoring station. An assessment was made based on professional judgement and limited data, and confidence is low.

Water quality is expected to stay the same as at present under all scenarios, as there is insufficient data to indicate whether there would be an overall improvement in WQ category with increased flows. However, improvements during the wet season will probably not be sufficient to improve overall status without source-directed controls and improved management of sulphate and phosphate sources in the catchment.

As the PES and ERC category for this reach of the river (set following Approach 2 of DWAF, 2002a) is a B/C, i.e. Lower Good category, the water quality Reserve category will be met under all scenarios.

Geomorphology (D)

For all scenarios flows are above the requested IFR. These flows are similar to present day. Geomorphology is unlikely to be improved by improved flows without adequate catchment management. The category remains a D for all scenarios.

Riparian Vegetation (Gorge, B/C; Rest, C)

Dry season, critical stress: Sufficient water is available to maintain existing mats of *Juncus* during the winter months. Stress values remain below 5 for >75% of the time. There is more than sufficient water available, and therefore a possible improvement in the category can be expected, to a B/C in the gorge, and a C in the other zones.

Wet season, critical stress: Stress values are well below 2 for >75% of the time. Therefore the existing mats should be maintained and the growth of new mats in the marginal areas is encouraged. An improvement in category would be expected, to a B/C in the gorge and a C in the other zones.

Fish (B/C)

Dry season: A stress of 5 - 6 for 20% of the time during the dry season occur. Habitat are maintained for *Amphilius* and *Labeobarbus*. There are better habitat and abundances than there would be in a moderate (C) condition, therefore there is an improvement in category.

Aquatic Invertebrates (B)

Dry season: A stress of 5 or less occurs for 80% of the time, which conforms to the stress level set for a B category. Thus conditions will be close to optimal.

Wet season: This scenario provides less stress than a B category. Habitats will be close to natural conditions.

Ecostatus (C)

If the individual categories of the recommended ERC are compared to Sc 3, they are all the same apart from riparian vegetation and fish that has improved. Comparing the stress profiles, the Sc 3 profile is considerably better than the C IFR profile. However, it was felt that this will still fall within at the higher end of the C band. If anything it could be a B/C, however insufficient information was available to make this decision.

8.5 Sc 6 CONSEQUENCES**Water quality (B/C)**

See Sc 3.

Geomorphology (D)

See Sc 3.

Riparian Vegetation (Gorge, B/C; Rest, C)

See Sc 3.

Fish (C)

Dry season: A stress 5 - 7 for 35% of the time exists. There is less dry habitat for *Amphilius natalensis*, but the majority of habitat is still available for *Labeobarbus natalensis*. Moderate abundances occur.

Aquatic Invertebrates

See Sc 3.

Ecostatus (C)

The only change compared to Sc 3 was a half a category lowering of the fish component. The C Ecostatus was still warranted therefore. The profile is also considerably closer to the C profile than to the D profile.

8.6 Sc 8 CONSEQUENCES**Water quality (B/C)**

See Sc 3.

Geomorphology (D)

See Sc 3.

Riparian Vegetation (Gorge, C; Rest, D)

Dry season, critical stress: Stress values remain below 5 therefore there is sufficient water to maintain existing mats. There is less water than for the overall C category, however the category is likely to be maintained as a C in the gorge and a D in the other zones.

Wet season, critical stress: Stress values remain well below 2 for >70% of the time. Thus, existing sites will be maintained and possibly new mats will be encouraged.

Fish (C/D)

A stress of 5 - 7 for 60% of the time occur, resulting in the loss of much habitat for *Amphilius*, however *Labeobarbus* habitat are still available. Slightly lower abundances occur than required for a C condition.

Aquatic Invertebrates (C)

Dry season: A stress of 6 occurs <70% of the time, thus providing good habitat. The stress curve lies similar to the D curve which equates to a C for invertebrates. Thus the category is considered to be a C.

Wet season: Stress conditions are low (less than B category) with the exception of 3% of the time.



















Ecostatus (C/D)

All categories are the same as the C IFR apart from fish and invertebrates which is a half category lower. The category as well as the profile is in general better than the D and the Ecostatus was therefore set at half a category lower, i.e. a C/D.

8.7 COMPARISON OF SCENARIOS

A comparison of the scenarios is illustrated in Table 8.1 below.

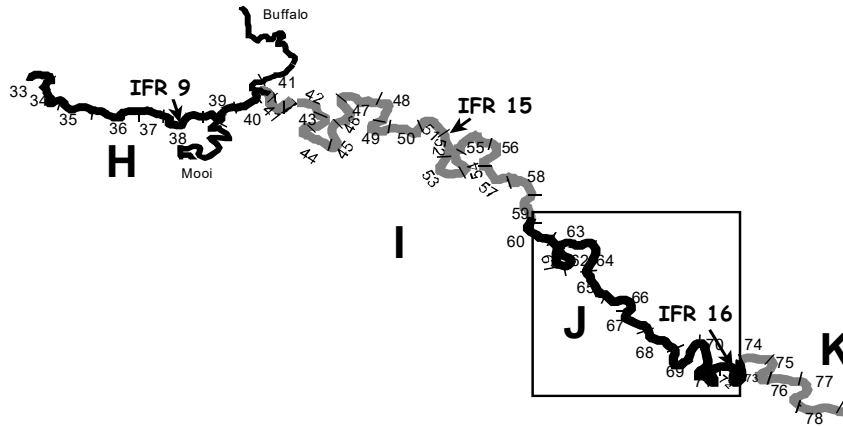
Table 8.1 Comparison of the ecological consequences of scenarios – IFR 15

Sc	EC	Worse		Same				Improved		
2,3 	C									
5,6 	C									
7,8 	C/D									

8.8 CONSIDERATION OF NON-FLOW RELATED ISSUES

When considering non-flow related alien fish problems, the fish category would drop half a class. The ERC for Water quality of a C category will also not be met without source-directed controls and improved management of magnesium salts. Both of these changes will not affect the overall Ecostatus under all the scenarios.

9 ECOLOGICAL CONSEQUENCES: IFR 16



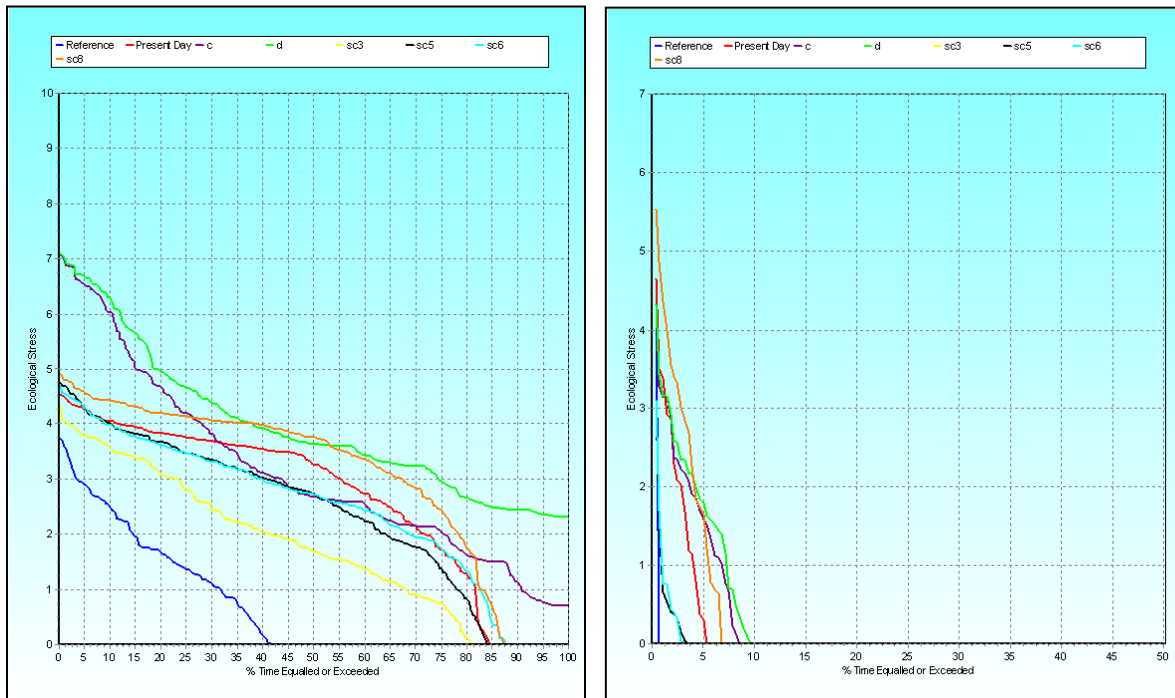
9.1 SCENARIOS REQUIRING EVALUATION

The following scenarios were found to be similar and therefore only Sc 3, 6 and 8 were evaluated.

Note:
Sc 2 = Sc 3
Sc 5 = Sc 6
Sc 7 = Sc 8

9.2 SCENARIOS CONVERTED TO STRESS PROFILES

Fig 9.1 Dry (left) and wet (right) season stress profiles





9.3 RESULTING ECs FOR EACH SCENARIO

The resulting EC for each component and for the Ecostatus is provided in Figure 9.2. The PES, long-term resulting trajectory and ERC are also provided for reference purposes. This

information was determined during a previous phase in the project and is provided in DWAF, 2003b (DWAF Report No. PBV000-00-10303).

The motivation for each component EC is provided in the sections below.

Fig 9.2 Resulting component status and Ecostatus

COMPONENT	PES	LONG TERM (20 Y)	ERC	DOWN	Sc3	Sc 6	Sc 8
WATER QUALITY	C	C/D	C		C	C	C/D
GEOMORPH	C/D	D	C/D	D	C/D	C/D	C/D
RIPARIAN VEGETATION	D	D/E	D	D	D	D	D/E
FISH	C	C	C	D	B/C	C	D
AQUATIC INVERTS	C	C/D	C	D	B/C	C	D
ECOSTATUS	C/D	D	C/D	D	 C	 C/D	D

9.4 Sc 3 CONSEQUENCES

Water quality (C)

The PES category for this section (set following Approach 2 of DWAF, 2002) is a C (or Upper Fair) category, vs. the B category previously set using Approach 1 of DWAF (1999). The new methods have therefore dropped the present EC by a category. Conditions will stay stable under scenarios 3 and 6.

Geomorphology (C/D)

For all scenarios flows are above the requested IFR. These flows are similar to present day conditions. Geomorphology is unlikely to be improved by improved flows without catchment management.

Riparian Vegetation (D)

Vegetation at this site is only suitable for high flow assessments. Extensive grazing and browsing in the area of the site and the influence of the small tributary on the right bank precludes the possibility of assessing low flows at this site. No appropriate low flow species were present to compile a stress profile. The site was selected for the possibility of elevated flows assessments only. Assessment of scenarios is therefore based on a theoretical understanding of the status and condition of the vegetation present. No ecological details or motivations are possible, just an estimate of condition based on flow scenarios.

Fish (B/C)

Wet season: Abundant habitat is available. Pools, marginal vegetation and sandy areas provide very good habitat. There is good breeding success as well as survival success of adults and juveniles. Moderate to high abundances occur.

Aquatic Invertebrates (B/C)

Dry season: Stress levels similar to the C/D category (C for invertebrates), where 55% of the time stress <5. Therefore a C category is assigned.

Wet season: Stress levels of 2 or less occur for 95% of the time, easily meeting criteria for a B category which requires stress levels of 2 or less for 70% of the time. Therefore, a category A/B.

Ecotatus (C)

All categories are the same as the C/D IFR apart from fish and invertebrates which is a half a category higher. Comparing the stress profiles, it was expected that the Ecotatus could be higher, i.e. a C category.

9.5 Sc 6 CONSEQUENCES**Water quality (C)**

See Sc 3.

Geomorphology (C/D)

See Sc 3.

Riparian Vegetation (D)

See Sc 3.

Fish (C)

Wet season: Good habitat for all species in pools, marginal vegetation, etc. There is good breeding success and survival of adults and juveniles. Moderate abundances occur.

Aquatic Invertebrates (C)

Dry season: This scenario remains close to the C/D category (C for invertebrates) where stress is less than 5 for 40% of the time. Therefore a category C is assigned.

Wet season: Stress levels of 2 or less occur for 94% of the time (which meets the criteria for a B category) and at stress 5 is still better than the B category. Therefore a category B is assigned.

Ecotatus (C/D)

All categories are the same as the C/D IFR and the Ecotatus therefore has to be the same, i.e. a C/D.

9.6 Sc 8 CONSEQUENCES**Water quality (C/D)**

Under scenario 8, overall WQ will drop to a C/D category (using the methods of DWAF (2002)). The water quality Reserve of a C category will therefore not be met under this scenario.

Geomorphology (C/D)

See Sc 3.

Riparian Vegetation (D/E)

See Sc 3.

Fish (D)

Wet season: A reduction in pool size and marginal vegetation in particular, results in lowered abundance and breeding success of most species.

Aquatic Invertebrates (D)

Dry season: This scenario is one stress level higher than the D category, but stresses of <5 occur for 30% of the time, therefore category D.

Wet season: This is similar to the D category but has higher stress levels for 7% of the time. Therefore a category D.
















Ecostatus (D)

When compared to the D IFR, fish and invertebrates are the same categories, riparian vegetation is worse, and geomorphology is half a category better. The Ecostatus therefore has to be lower than the Sc 6 and was set to a D category.

9.7 COMPARISON OF SCENARIOS

A comparison of the scenarios is illustrated in Table 9.1 below.

Table 9.1 Comparison of the ecological consequences of scenarios – IFR 16

Sc	EC	Worse				Same					Improved	
2, 3 ↑	C											
5, 6 ↔	C/D											
7, 8 ↓	D											

9.8 CONSIDERATION OF NON-FLOW RELATED ISSUES

To achieve a water quality ERC of a C category, magnesium sulphate and magnesium chloride concentrations will have to be improved to a D and B category respectively. It must be noted that although moderately elevated sulphate levels do exist, Mg levels, and subsequently magnesium sulphate, may be erroneous. The predicted high levels of magnesium may be an error due to the application of the EWQRCalc model Version 2.3 (as required by the new water quality method of DWAf, 2002a) used to define benchmark values for inorganic salts, which appears to over-estimate magnesium sulphate concentrations (Jooste, RQS, *pers. comm.*).

If improved management practices are not implemented, the overall WQ status of a C category will not be achieved.

If non-flow related alien fish problems are considered, the fish category would drop by half a category.

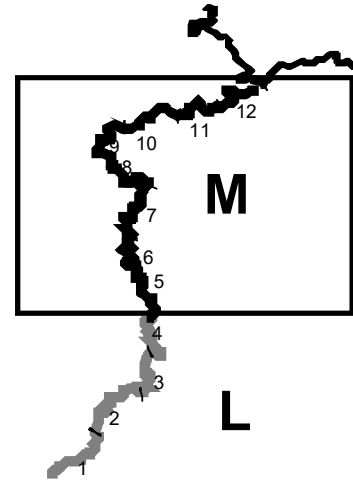
Under Sc 3 and Sc 6, fish and invertebrates would drop half a class, which may affect the Ecostatus down to a C/D. Additional water is not going to help the non flow related problems. Management intervention is required.

10 ECOLOGICAL CONSEQUENCES: IFR 3

10.1 SCENARIOS REQUIRING EVALUATION

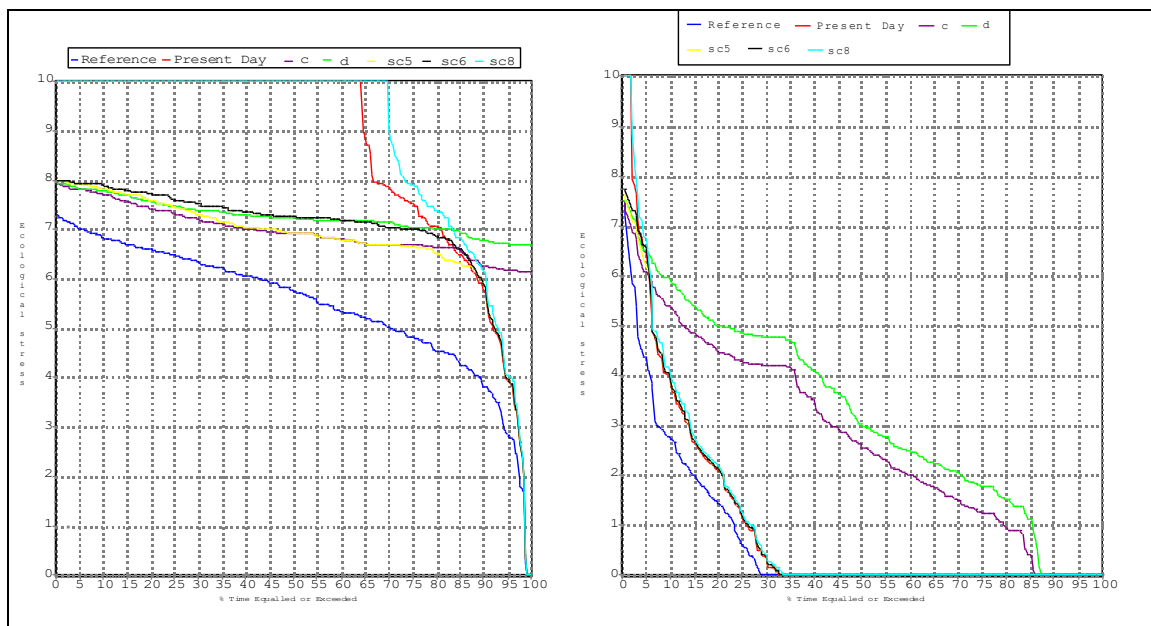
The following scenarios were found to be similar and therefore only Sc 5, 6 and 8 were evaluated.

Note:
Sc 2 = Sc 5
Sc 3 = Sc 6
Sc 7 = Sc 8



10.2 SCENARIOS CONVERTED TO STRESS PROFILES

Fig 10.1 Dry (left) and wet (right) season stress profiles



10.3 RESULTING ECS FOR EACH SCENARIO

The resulting EC for each component and for the Ecostatus is provided in Figure 10.2. The PES, long-term resulting trajectory and ERC are also provided for reference purposes. This information was determined during a previous phase in the project and is provided in DWAF, 2003b (DWAF Report No. PBV000-00-10303).

The motivation for each component EC is provided in the sections below.

Fig 10.2 Resulting component status and Ecostatus

COMPONENT	PES	LONG TERM (20 Y)	ERC Sc 2	DOWN Sc 3 (6)	Sc 5 (2)	Sc 6 (3)	Sc 8
WATER QUALITY	B/C	B/C	B/C		B/C	B/C	B/C
GEOMORPH	C/D	D	C/D	D	C/D	C/D	C/D
RIPARIAN VEGETATION	D/E	E	D	D	D	E	F
FISH	C	C	C	D	D	D/E	F
AQUATIC INVERTS	B/C	C	B/C	C/D	B/C	C	F
ECOSTATUS	C/D	D	C/D	D	C/D	D	F

10.4 Sc 5 CONSEQUENCES

Water quality (B/C)

Water quality is expected to stay the same as present under all scenarios, including scenario 8 as it is similar to present EC. Conditions should improve under scenarios 5 and 6 in the dry season (as periods of low flow now avoided), but may not be sufficient to improve the overall water quality category. The implication is that the water quality Reserve category will be met under all scenarios.

Geomorphology (C/D)

Scenarios 5, 6 and 8 appear to be very similar to the present day flow. This flow volume is higher than that required for the IFR. This site has non flow-related problems and therefore higher flows are unlikely to change the category, i.e. it remains a C/D.

Riparian Vegetation (D)

Mixed grasses, adult

Dry season, critical stress of 7.1: Sufficient water is available to maintain existing clumps of mixed grasses during winter. Therefore maintain the present category D.

Dry season, critical stress of 8: Older clumps die off less often than required (< 5% of the time. Stress >8 for less than 98% of the time. Therefore maintain category (D).

Salix adults

Dry season, critical stress of 4: Stresses of 4 or more occur > 80% of the time, therefore *Salix* individuals are unlikely to be maintained during winter. These plants are likely to experience extreme moisture stress, with loss of leaves and stems. There is a loss of existing *Salix* individuals.

Dry season, critical stress of 8: Older individuals will die off less frequently than required in SC2, thus not making it possible for colonisation by young healthier individuals. Stress values of < 8 occur for 98% of the time. Maintain D category.

Fish (D)

Dry season: A moderate to low survival rate of *Amphilius natalensis* in riffles. A stress > 7 for 45% of the time exists.

Aquatic Invertebrates (B/C)

Dry season: A stress of 7.5 or less occurs for 75% of the time compared to the requirement of 7.5 of 50% of the time for a category B/C. Therefore, the category B/C is maintained.

Wet season: Flows are close to natural stress.

Ecostatus (C/D)

All components are the same as for the C/D IFR apart from fish which is one category less. The Ecostatus therefore remains the same. Furthermore, the stress profile for the C/D IFR and for Sc 5 are very similar.

10.5 Sc 6 CONSEQUENCES**Water quality (B/C)**

See Sc 5.

Geomorphology (C/D)

See Sc 5.

Riparian Vegetation (E)**Mixed grasses, adult**

Dry season, critical stress of 7.1: Stress levels > 7.1 are provided for 70% of the time, therefore existing clumps of mixed grasses are likely to be reduced due to insufficient water. Probable reduction in category to E.

Dry season, critical stress of 8: Older clumps die off less often than required (<5% of the time. Stress >8 for less than 98% of the time.

Salix adults

Dry season, critical stress of 8: Older individuals will die off less frequently than required in Sc5, thus not making it possible for colonisation by young healthier individuals. Stress values of < 8 occur for 98% of the time. Maintain D category.

Fish (D/E)

Dry season: A stress above 7 for >75% of the time is present, very high mortalities of *Amphilius natalensis*, with critically low survival rates.

Aquatic Invertebrates (C)

Dry season: This scenario is slightly more stressed than the D category (C/D for invertebrates). Therefore, C/D category.

Wet season: This scenario is slightly more stressed than the D category (C/D for invertebrates). Therefore, A/B category.

Ecostatus (D)

Sc 6 is worse than Sc 5 as riparian vegetation, fish, and aquatic invertebrates have dropped a category. Both riparian vegetation and fish have dropped to an unacceptable category. Considering the decrease in categories, as well as the fact that the D IFR stress profile is virtually the same than the Sc 6 profile, the Ecostatus has to be a D.

10.6 Sc 8 CONSEQUENCES**Water quality (B/C)**

See Sc 5.

Geomorphology (C/D)

See Sc 5.

Riparian Vegetation (F)**Mixed grasses, adult**

Dry season, critical stress of 7.1: Insufficient water is available during winter months, therefore existing clumps will experience excessive stress and experience significant die-off. A probable reduction in category from E to F is needed.

Dry season, critical stress of 8: Stresses of >8 occur very frequently in winter, leading to the reduction in older clumps and a drop in category to E.

Salix adults

Dry season, critical stress of 4: Extensive levels of Plant Moisture Stress (PMS) is experienced, leading to die off of individuals, thus a drop in category likely, to E.

Dry season, critical stress of 8: Stresses of >8 occur very frequently leading to excessive die-off of older and less healthy individuals.

Fish (F)

Dry season: Dry bed.

Aquatic Invertebrates (F)

Unacceptable flow both in dry and wet seasons.

























Ecostatus (F)

As this scenario includes long periods of no flow which is unacceptable, the Ecostatus has to be an F. This is further supported in that all the biological components have decreased to a F category.

10.7 COMPARISON OF SCENARIOS

A comparison of the scenarios is illustrated in Table 10.1 below.

Table 10.1 Comparison of the ecological consequences of scenarios – IFR 3

Sc	EC	Worse			Same			
2, 5 	C/D							
3, 6 	D							
7, 8 	F							

10.8 CONSIDERATION OF NON-FLOW RELATED ISSUES

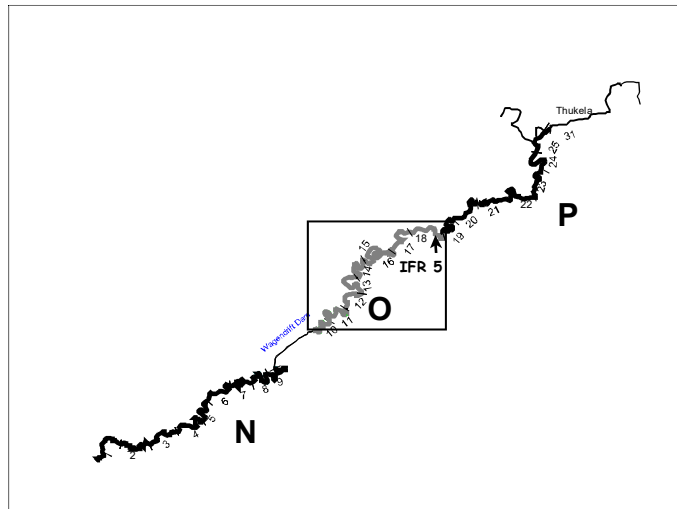
For all the scenarios the vegetation will drop by half a category considering non-flow related issues. This will however not affect the Ecostatus under all the scenarios.

11 ECOLOGICAL CONSEQUENCES: IFR 5

11.1 SCENARIOS REQUIRING EVALUATION

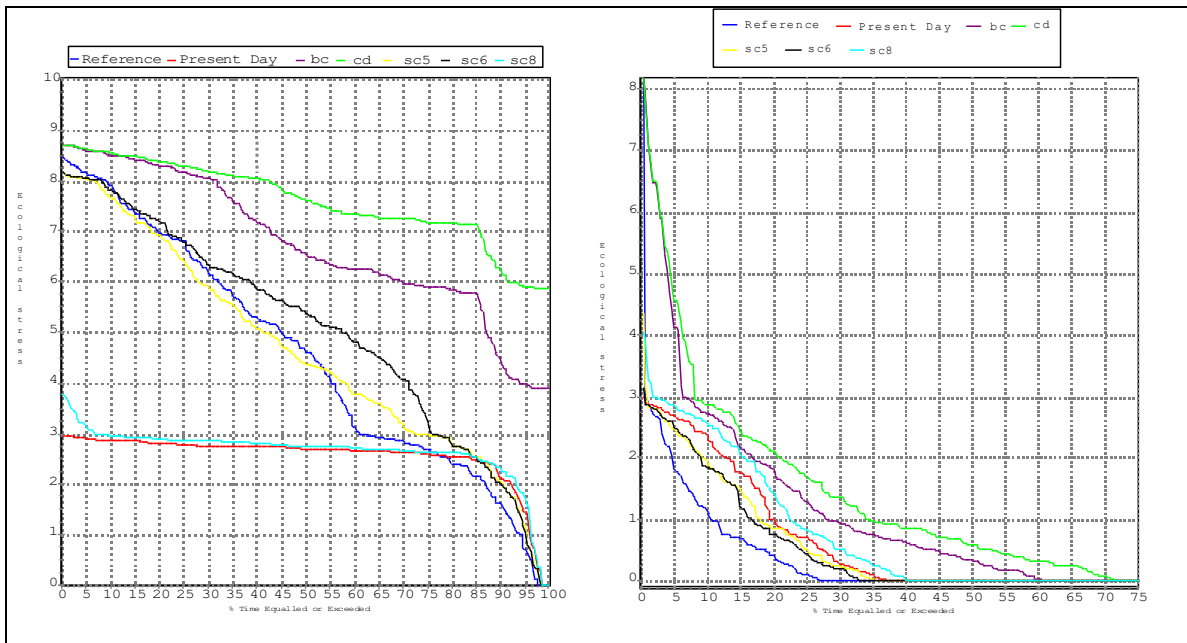
The following scenarios were found to be similar and therefore only Sc 5, 6 and 8 were evaluated.

Note:
Sc 2 = Sc 5
Sc 3 = Sc 6
Sc 7 = Sc 8



11.2 SCENARIOS CONVERTED TO STRESS PROFILES

Fig 11.1 Dry (left) and wet (right) season stress profiles




11.3 RESULTING ECs FOR EACH SCENARIO

The resulting EC for each component and for the Ecostatus is provided in Figure 11.2. The PES, long-term resulting trajectory and ERC are also provided for reference purposes. This information was determined during a previous phase in the project and is provided in document PDV000-00-10303.

The motivation for each component EC is provided in the sections below.

Fig 11.2 Resulting component status and Ecostatus

COMPONENT	PES	LONG TERM (20 Y)	ERC Sc 2	DOWN Sc 3	Sc 5 sup	Sc 6	Sc 8
WATER QUALITY	B/C	C	B/C		C	C	B/C
GEOMORPH	B/C	C	B/C	C/D	B	B	B
RIPARIAN VEGETATION	B/C	C	B/C	C/D	A/B	B	C/D
FISH	C	D	C	D	A/B	B/C	D
AQUATIC INVERTS	C	C/D	C	D	A	A/B	C
ECOSTATUS	B/C	C	B/C	C/D	 A/B	B	C

11.4 Sc 5 CONSEQUENCES

Water quality (C)

Under all scenarios in the wet season, water quality conditions would remain as at present, i.e. B/C. In the dry season, scenarios 5 and 6 would cause deterioration in water quality, and drive the water quality category to a C category. The water quality reserve would not be met under scenarios 5 and 6 – source-directed controls would be required to improve the conditions of phosphates in the catchment. Available information suggests that there may be water quality impacts associated with Estcourt's sewage effluent, overgrazing, and bottom releases from Wagendrift Dam. As there is minimal data, no modeling information, and no data for the wet season (data collected in August and September 2001), assessments are at a low confidence level.

Geomorphology (B)

Higher flows (20 - 40m³/s) occur more frequently than required by the IFR. These flows approximate the present day condition. Assuming that these flows are going to be managed as flood peaks, this may result in an improvement in the category.

Riparian Vegetation (A/B)

Increased water availability in both summer and winter, leads to reduced exposure of roots and leaf wilting. This encourages the maintenance of existing clumps of *Setaria* and healthy recruitment. There is an overall increase in category to A/B.

Wet season, critical stress of 3: An increased water availability in summer exists, with almost no stresses > 3. This encourages maintenance of existing clumps with healthy recruitment in late summer resulting in an increase in category.

Dry season, critical stress of 5: Increased water availability: Leaf wilting occurs less frequently as roots are exposed for brief periods in winter. There is an increase category to A/B.

Dry season, critical stress of 8: Thinning of weaker individuals occurs 5% of time as required. A category B/C is maintained.

Fish (A/B)

This is close to natural conditions. Relative abundance of each species is likely to fluctuate seasonally and under varying stress levels. However, the presence of aliens that may take advantage of a slight drop in abundance of indigenous species and could result in it

becoming a B category. The presence of aliens is not considered a flow-related issue, but in this reach the relative abundance and/or success of alien species is influenced by flow). The use of the Fish Integrity Index to determine the category is illustrated in Table 11.1³

Table 11.1 Determination of the resulting fish category for the different flow scenarios

Resource Unit	IFR 5.5	IFR 5.6	IFR 5.8
Native species richness	5	5	5
Presence of native intolerant species	5	4	2
Abundance of native species	4	3	2
Frequency of occurrence of native	4	4	2
Health/condition of native and introduced species	4	4	2
Presence of introduced fish species	3	3	1
In-stream habitat modification	4	4	2
TOTAL FISH SCORE	29	27	16
%	82.9	77.1	45.7
FISH ASSEMBLAGE CATEGORY	B	C	D

Aquatic Invertebrates (A)

This scenario almost perfectly matches the reference conditions, providing the correct mix of high and low stress conditions.

Ecostatus (A/B)

All the components apart from water quality improve, as some considerably. There is therefore sufficient motivation to increase the Ecostatus by a category to A/B. This is further motivated by the stress profile which is virtually the same reference conditions. It must be noted however that there is a low confidence in the actual flow conditions at the site itself, as well as the fact that this water would be artificially managed from a dam. Taking this as well as the black flag into account, it is unlikely that this would be the realistic EC of the river if Sc 5 is implemented.

11.5 Sc 6 CONSEQUENCES

Water quality (C)

See Sc 5.

Geomorphology (B)

See Sc 5.

Riparian Vegetation (B)

There is increased water availability in both winter and summer, reducing water stress and root exposure and there is an encouragement of maintenance of existing clumps of *Setaria*, as well as recruitment. Increase in category to a B.

Wet season, critical stress of 3: Increased water availability in summer exists, with almost no stresses > 3. This encourages maintenance of existing clumps with healthy recruitment in late summer. Increase in category.

Dry season, critical stress of 5: There is increased water availability, thus leaf wilting is less frequent but there are enough periods to result in leaf wilting in the winter. Increase category to B.

Dry season, critical stress of 8: Thinning of weaker individuals occur 5% of the time as required.

³ The scoring system is explained in Report PBV000-00-10303, Appendix E.

Fish (B/C)

Similar to Sc 5, but there is a slightly higher stress in the dry seasons therefore the drop in category. The use of the FAIL to determine the category is illustrated in Table 11.1.

Aquatic Invertebrates (A/B)

Dry season: This scenario has more stress in the system during moderate flows, which occur most frequently, but their stress levels are insignificant for invertebrates.

Wet season: Stress conditions for this scenario are (for invertebrates) indistinguishable from natural conditions and therefore a category A.

Ecostatus (B)

Riparian vegetation, fish and aquatic invertebrates are down in category. There is sufficient motivation to decrease the Ecostatus from that of Sc 5. As the stress profile is still at certain stress conditions close to natural, the Ecostatus is only dropped by half a category to a B.

11.6 Sc 8 CONSEQUENCES**Water quality (B/C)**

The water quality ERC would be maintained as the flow conditions at present is similar to Sc 8.

Geomorphology (B)

See Sc 5.

Riparian Vegetation (C/D)

There is increased water in summer and a constant increase in winter. This generally encourages extensive mats with no resilience and artificial densities of grasses. Therefore a reduction in category to C/D.

Wet season, critical stress of 3: An increased water availability in summer with stresses of > 3 for 2% of the time exists. Maintain existing category.

Dry season, critical stress of 5: A continuous supply of water in winter ensures that the roots are never exposed. No resilience tempering. There is a reduction in category to C/D.

Dry season, critical stress of 8: No thinning occurs at all due to the constant and increased water in winter, thus no resilience tempering. Category reduces to C/D

Fish (D)

There is low stress. The lack of variability leads to dominance by one or two species which in this case are likely to be the alien/introduced species. The reasoning for this is the same as that for Sc 5 and 6. The use of the FAIL to determine the category is illustrated in Table 11.1.

Aquatic Invertebrates (C)

Dry season: This scenario presents a totally unstressed situation all year round, which is detrimental to biodiversity and ecological health. Category C.

Wet season: For 98% of summer, there is no significant stress on this system, thus essentially the same as natural. Category A/B.
















Ecostatus (C)

There is a spread of categories present, ranging from a D to a B. This is a complex situation as the flows will be significantly higher than natural during the dry season. Assuming that natural is an A, an increased flow condition will decrease in category. It is very difficult to predict the level of change that would be caused by constantly increased flows, and therefore the conservative estimate of a C category has a low confidence.

11.7 COMPARISON OF SCENARIOS

A comparison of the scenarios is illustrated in Table 11.2 below.

Table 11.2 Comparison of the ecological consequences of scenarios – IFR 5

Sc	EC	Worse			Same		Improved			
2, 5 ↑	A/B									
3, 6 ↑	B									
7, 8 ↓	C									

11.8 CONSIDERATION OF NON-FLOW RELATED ISSUES

Due to the presence of alien fish, the fish category would drop in Sc 5. The water quality problems would likely drop the aquatic invertebrates category and the Ecstatus will then be a B.

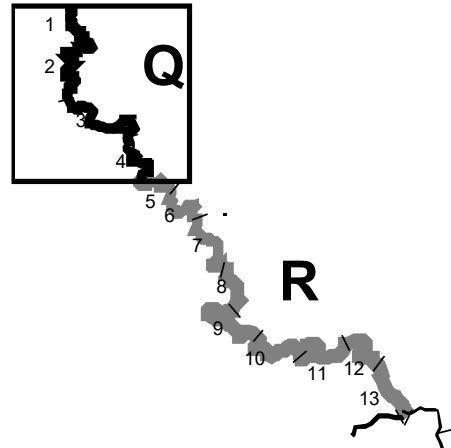
Invertebrates will also drop a category in Sc 6, but this will not change the Ecstatus.

12 ECOLOGICAL CONSEQUENCES: IFR 7

12.1 SCENARIOS REQUIRING EVALUATION

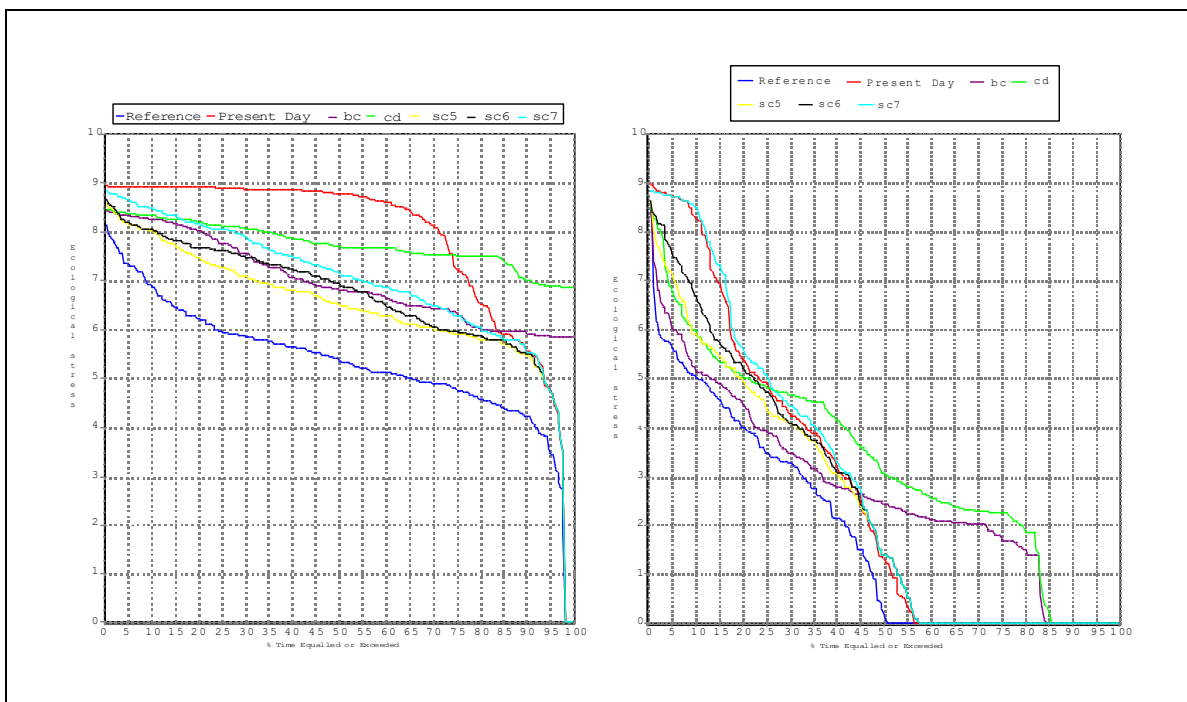
The following scenarios were found to be similar and therefore only Sc 5, 7 and 8 were evaluated.

Note:
Sc 2 = Sc 5
Sc 3 = Sc 6 = Sc 8



12.2 SCENARIOS CONVERTED TO STRESS PROFILES

Fig 12.1 Dry (left) and wet (right) season stress profiles



12.3 RESULTING ECs FOR EACH SCENARIO

The resulting EC for each component and for the Ecstatus is provided in Figure 12.2. The PES, long-term resulting trajectory and ERC are also provided for reference purposes. This information was determined during a previous phase in the project and is provided in DWAF, 2003b (DWAF Report No. PBV000-00-10303).

The motivation for each component EC is provided in the sections below.

Fig 12.2 Resulting component status and Ecostatus

COMPONENT	PES	LONG TERM (20 Y)	ERC	DOWN	Sc 5 (2)	Sc 6 (3 & 8)	Sc 7
WATER QUALITY	C	C/D	B/C		C	C	C
GEOMORPH	B/C	C	B/C	C/D	B	B	B
RIPARIAN VEGETATION	B/C	?	B/C	C/D	B	B/C	C
FISH	B	B	B	C	B	B	B
AQUATIC INVERTS	C	C	C	D	C	C/D	D
ECOSTATUS	B/C	C	B/C	C/D	B	B/C	C

12.4 Sc 5 CONSEQUENCES

Water quality (C)

Although more water occurs in the dry season, and TDS would probably remain in an A category; sulphate conditions are so poor (category E/F) that they are not expected to improve sufficiently enough to change the overall water quality status, SRP and TIN would remain as present. Overall water quality would therefore not improve due to the elevated sulphate levels.

Geomorphology (B)

Wet season flows indicate higher flows than the required IFR. Assuming the flows are managed as flood peaks, fine sediments will continuously be mobilised, keeping habitats clean and open. These flows should provide an improvement from B/C to B for all scenarios.

Riparian Vegetation (B)

There are lower stress levels in winter, encouraging the widening of the riparian zone, and slightly higher levels in summer, leading to thinning. Overall, this will result in the maintenance of existing clumps of *Setaria*.

Dry season, critical stress of 9.8: More water is available with lower stress levels, generally encouraging the maintenance of existing clumps of *Setaria*. This will probably increase the width of the marginal zone. The category increases to a B.

Dry season, critical stress of 8: Stresses of 8 and above for 5% of the time will lead to the appropriate death of older clumps, and sufficient resilience tempering. The category is maintained.

Wet season, critical stress of 3.3: Essentially more stress during summer, discouraging the total maintenance of existing clumps; possibly with thinning of *Setaria* on higher-lying terraces due to excessive moisture stress. The category is possibly maintained.

Fish (B)

All fish present are tolerant native species. There is little difference in stress between Sc 5,6 and 7. The use of the FAIL to determine the category is illustrated in Table 12.1.

Table 12.1 Determination of the resulting fish category for the different flow scenarios

Resource Unit	IFR 7.5	IFR 7.6	IFR 7.8
Native species richness	4	4	4
Presence of native intolerant species	5	5	5
Abundance of native species	3	3	3
Frequency of occurrence of native	5	5	4
Health/condition of native and introduced species	5	5	5
Presence of introduced fish species	5	5	5
In-stream habitat modification	4	4	4
TOTAL FISH SCORE	31	31	30
%	88.6	88.6	85.7
FISH ASSEMBLAGE CATEGORY	B	B	B

Aquatic Invertebrates (C)

Dry season: This scenario is better than the B/C (C for invertebrates) under all conditions. Invertebrates are also easily catered for by the critical stress. This category of invertebrates will be a B/C.

Wet season: This scenario mirrors the C/D situation (which is a D for invertebrates), especially in the high stress situation (> 5). Therefore a category D.

Ecostatus (B)

The geomorphology driver as well as riparian vegetation has improved by half a category. Sc 5 now has three components in a B, one in a B/C and one in a C. This warrants a B Ecostatus. Investigating the stress profiles, the Sc 5 profile is marginally better than the B/C IFR profile in the dry season, and better in the wet season at high stress for a large proportion of the time. This further supports the B Ecostatus.

12.5 Sc 6 CONSEQUENCES**Water quality (C)**

See Sc 5.

Geomorphology (B)

See Sc 5.

Riparian Vegetation (B/C)

Essentially the same amount of water and stress levels as for category B/C. Maintains an existing category of a B/C.

Fish (B)

See Sc 5.

Aquatic Invertebrates (C/D)

Dry season: This scenario mirrors the B/C line (C for invertebrates) under all conditions. Category C.

Wet season: This scenario is slightly more stressed than the C/D category especially during high stress conditions (> 5). Category D.

Overall category: Category C/D.

Ecostatus (B/C)

When comparing Sc 6 to the B/C ERC, all components are the same apart from Geomorphology which is half a category better and aquatic invertebrates which is half a

category worse. Compared to Sc 5 (B Ecstatus), the same two categories are half a category worse. This provides sufficient motivation for a B/C Ecstatus. The stress profiles supports this as the Sc 6 profiles are close to the B/C IFR profile, but slightly worse compared to the B Ecstatus of Sc 5.

12.6 Sc 7 CONSEQUENCES

Water quality (C)

Under scenario 7, i.e. present day, conditions would remain as at present, i.e. B/C – method according to DWAF (1999), and C – revised methods of DWAF (2002). The water quality Reserve category will therefore not be met under any scenarios unless sulphate pollution and coalmine drainage in this catchment is addressed.

Geomorphology (B)

See Sc 5.

Riparian Vegetation (C)

Generally higher levels of moisture stress and root exposure is present. Possibly maintain the existing category or reduce the category.

Dry season, critical stress of 9.8: There is a greater stress, generally resulting in higher levels of moisture stress and root exposure. Possibly maintain existing, or reduce category.

Dry season, critical stress of 8: Stresses of 8 for up to 20% of the time, encouraging excessive death of older and weaker individuals. A reduction in category to C.

Wet season, critical stress of 3.3: Excessive stress levels which is likely to lead to thinning of existing grasses on higher terraces and amongst older individuals.

Fish (B)

See Sc 5.

Aquatic Invertebrates (D)

Dry season: This scenario is closer to the B/C than to the C/D line. Category C.

Wet season: At high stress conditions (>5), this scenario is considerably more stressed than the C/D line (D for invertebrates). Therefore a Category D/E.

Overall category: Category D















Ecstatus (C)

When compared to the C/D IFR components, three categories are better. Compared to the B/C IFR, one category is better and two categories are worse. This then does not represent a B/C category, neither does it present a C/D category. The stress profiles illustrate that there is considerably less stress under the Sc 7 profile than the C/D profile and the Ecstatus of a C is therefore warranted.

12.7 COMPARISON OF SCENARIOS

A comparison of the scenarios is illustrated in Table 12.2 below.

Table 12.2 Comparison of the ecological consequences of scenarios – IFR 7

Sc	EC	Worse		Same				Improved	
2, 5 	B								
3, 6, 8 	B/C								
7 	C								

12.8 CONSIDERATION OF NON-FLOW RELATED ISSUES

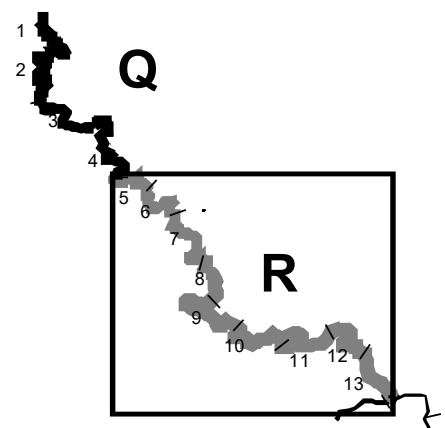
Even though all the problems are non-flow related, this does not affect the Ecstatus assessment under all scenarios.

13 ECOLOGICAL CONSEQUENCES: IFR 8

13.1 SCENARIOS REQUIRING EVALUATION

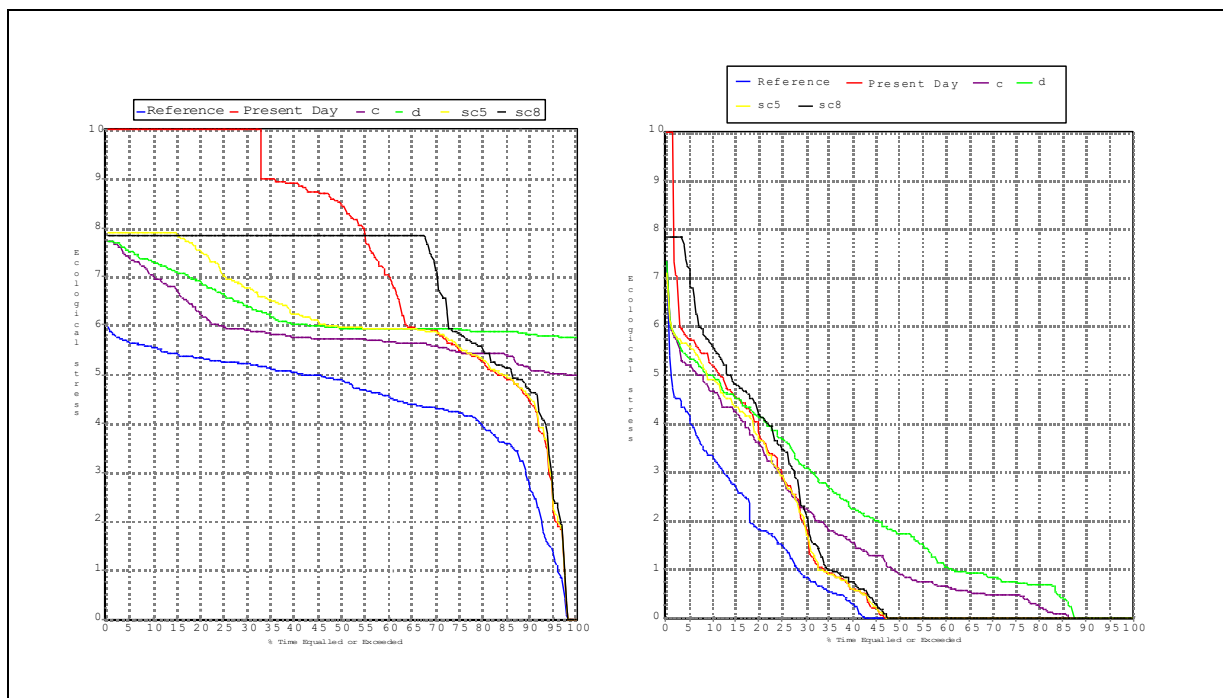
The following scenarios were found to be similar and therefore only Sc 6 and 8 were evaluated.

Note:
Sc 2 = Sc 3 = Sc 5 = Sc 6
Sc 7 = Sc 8



13.2 SCENARIOS CONVERTED TO STRESS PROFILES

Fig 13.1 Dry (left) and wet (right) season stress profiles



13.3 RESULTING ECs FOR EACH SCENARIO

The resulting EC for each component and for the Ecostatus is provided in Figure 13.2. The PES, long-term resulting trajectory and ERC are also provided for reference purposes. This information was determined during a previous phase in the project and is provided in DWAF, 2003b (DWAF Report No. PBV000-00-10303).

The motivation for each component EC is provided in the sections below.

Fig 13.2 Resulting component status and Ecstatus

COMPONENT	PES	LONG TERM (20 Y)	ERC	Sc 6	Sc 8
WATER QUALITY	C	C	C	C	C
GEOMORPH	D	D	D	C/D	C/D
RIPARIAN VEGETATION	E	E/F	D	D/E	F
FISH	C	C	C	C	D
AQUATIC INVERTS	B/C	B/C	B/C	C	E
ECOSTATUS	D	D/E	D	D	E

13.4 Sc 6 CONSEQUENCES

Water quality (C)

There is minimal water quality data for this site, no modeling information, and no data for the wet season (data collected weekly in August and September 2001). The present EC is in a C category, with elevated sulphate levels and periphyton levels. During the wet season, scenarios 6 and 8 are equivalent to present EC; no changes are therefore predicted. During the dry season, scenario 6 provides slightly more water, but probably not enough to improve the category, particularly as this is a low confidence site. The water quality reserve of a C category will be met under all scenarios, but source-directed controls and improvement to water quality status are required as magnesium sulphate and periphyton are currently in E/F categories.

This site is below the input of the Wasbank River, which brings water of poor quality to the Sundays (a PES category of C – C/D). Management of the Wasbank River catchment area will be required so as to reduce threats to the Sundays River system.

Geomorphology (C/D)

Wet season flows are higher than required for the IFR. These flows (if correctly managed) could rehabilitate this site from a D to a C/D. This site is recovering from extensive flood damage and therefore needs frequent overbank topping.

Riparian Vegetation (D/E)

Drop of category to D/E due to the impact of the dry season.

Dry season, critical stress of 5.7: Similar levels of stress for both scenarios, therefore maintain existing clumps of *Setaria* during winter.

Dry season, critical stress of 8: Extended stresses of 8 from < 1% for a D category up to 15% for Sc6, decrease in category possibly to D/E.

Wet season, critical stress of 4.5: Essentially better off or similar to D in maximum stress levels (maximum stresses of 7 for 1% of time). A possible maintenance of the category.

Fish (C)

The majority of species present are tolerant, sufficient pool habitat for dry season survival exists. Response to dry season stress would be dictated by available pools and tolerance of crowding. The use of the FAIL to determine the category is illustrated in Table 13.1.

Table 13.1 Determination of the resulting fish category for the different flow scenarios

Resource Unit	IFR 8.6	IFR 8.8
Native species richness	4	3
Presence of native intolerant species	2	1
Abundance of native species	3	2
Frequency of occurrence of native	2	2
Health/condition of native and introduced species	4	3
Presence of introduced fish species	5	5
In-stream habitat modification	3	2
TOTAL FISH SCORE	23	18
%	65.7	51.4
FISH ASSEMBLAGE CATEGORY	C	D

Aquatic Invertebrates (C)

Dry season: This scenario closely mirrors the D line (B/C for invertebrates) thus invertebrates are easily satisfied by the provided flows. Category is C.

Wet season: During the wet season invertebrates are easily catered for at this site, closely following the C and D lines (B and B/C for invertebrates). Category is thus a B/C.

Overall category: Category C

Ecostatus (D)

When compared to the D IFR components, geomorphology is better, and riparian vegetation and aquatic invertebrates are worse. The stress profile of Sc 6 is slightly worse at stages than the D IFR profile. This scenario could probably represent either a C/D or a D, but the low vegetation category (D/E) warrants a D Ecostatus.

13.5 Sc 8 CONSEQUENCES**Water quality (C)**

See Sc 6.

Geomorphology (C/D)

See Sc 6.

Riparian Vegetation (F)

There is a drop of category to an E/F or F mainly due to the impact of the dry season.

Dry season, critical stress of 5.7: Similar levels of stress for both scenarios, therefore maintain existing clumps of *Setaria* during winter.

Dry season, critical stress of 8: Extended stresses of 8 from <1% for D category up to 70% for Sc6. Decrease in category possibly to F.

Wet season, critical stress of 4.5: Significantly higher stresses to 8 for up to 5% of the time, leads to a drop in category due to thinning.

Fish (D)

The fish assemblage is confined to tolerant species, intolerant species are extinct from the reach and tolerant species are subject to severe stress in dry season pools. The use of the FAIL to determine the category is illustrated in Table 13.1.

Aquatic Invertebrates (E)

Dry season: High stress (8 - 7 for invertebrates) sustained for 65% of the dry season which will result in the loss of many rheophilic species. Category E.

Wet season: For much of the wet season Sc 8 tracks the D line (B/C for invertebrates) but becomes more stressed during drought conditions. Category C.

Overall category: Category E.














Ecostatus (E)

Sc 8 is considerably worse than Sc 6 with two categories below a D as well as fish dropping a full category. Taking the stress conditions associated with this scenario during the dry season into account, this scenario results in unacceptable ecological condition with an Ecostatus of an E.

13.6 COMPARISON OF SCENARIOS

A comparison of the scenarios is illustrated in Table 13.2 below.

Table 13.2 Comparison of the ecological consequences of scenarios – IFR 8

Sc	EC	Worse			Same		Improved
2, 3, 5, 6 	D						
7, 8 	E				 		

13.7 CONSIDERATION OF NON-FLOW RELATED ISSUES

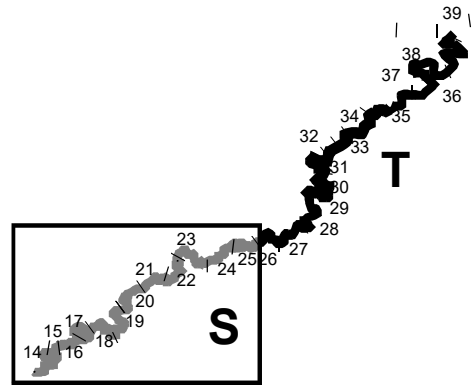
The vegetation will decrease from a D/E to an E in Sc 6 when considering non-flow related issues. This will however not affect the D Ecostatus under Sc 6.

14 ECOLOGICAL CONSEQUENCES: IFR 10

14.1 SCENARIOS REQUIRING EVALUATION

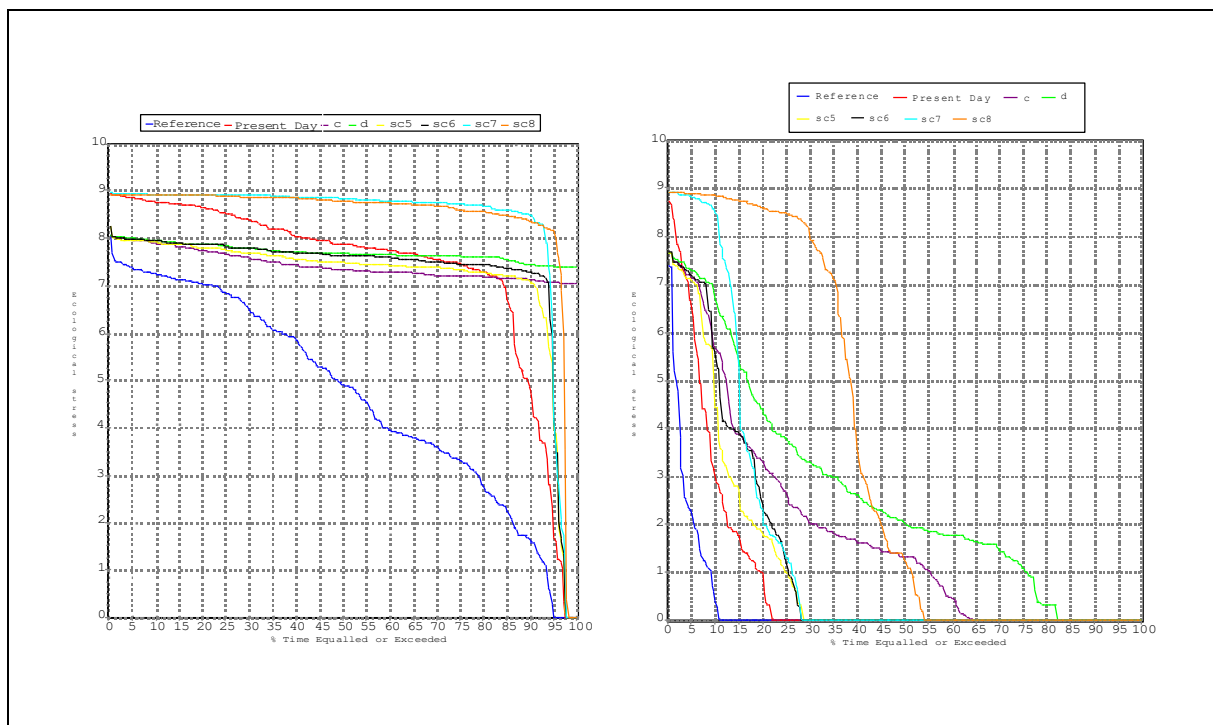
The following scenarios were found to be similar and therefore only Sc 5, 6, 7 and 8 were evaluated.

Note:
Sc 2 = Sc 5
Sc 3 = Sc 6



14.2 SCENARIOS CONVERTED TO STRESS PROFILES

Fig 14.1 Dry (left) and wet (right) season stress profiles



14.3 RESULTING ECs FOR EACH SCENARIO

The resulting EC for each component and for the Ecostatus is provided in Figure 14.2. The PES, long-term resulting trajectory and ERC are also provided for reference purposes. This information was determined during a previous phase in the project and is provided in DWAF, 2003b (DWAF Report No. PBV000-00-10303).

The motivation for each component EC is provided in the sections below.

Fig 14.2 Resulting component status and Ecstatus

COMPONENT	PES	LONG TERM (20 Y)	ERC	DOWN	Sc 5 (2)	Sc 6 (3)	Sc 7	Sc 8
WATER QUALITY	B	B	B		B	B	B	B
GEOMORPH	C	C	C	D	C	C	C	D
RIPARIAN VEGETATION	C/D	C/D	C/D	D	C/D	C/D	D	D/E
FISH	C	C	C	D	C/D	C/D	E	E
AQUATIC INVERTS	B/C	B/C	B/C	C/D	C	C	E	E
ECOSTATUS	C	C	C	D	C	C/D	E	E

14.4 Sc 5 CONSEQUENCES

Water quality (B)

Scenarios 5 and 6 should improve the nutrient and periphyton status, thereby improving the present water quality status and achieving the ERC of a B category. Note that the method of DWAF (2002) places the present EC at a B category, and not a B/C category, as assigned using DWAF (1999).

Geomorphology (C)

There are no flow-related issues to be dealt with at this site. During the wet season, flows appear adequate to maintain the present class as a C.

Riparian Vegetation (C/D)

Dry season, critical stress of 7: Marginally worse levels of stress generally during winter. However, this is unlikely to result in losses and thinning of grasses. Therefore, maintain the category.

Dry season, critical stress of 8: Maintain existing and lower rates of die-off of older rates. Stress = 8, therefore maintain category to temper resilience during winter.

Wet season, critical stress of 5: Marginally less frequent stress levels above stress 2: with less consistent stresses < 2 during summer. Maintain category as C.

Fish (C/D)

There is reduced inundation of marginal areas and riffles during the wet season, therefore spawning or breeding habitat for indigenous species is reduced. During the dry season fish are confined to pools with a degree of overcrowding. Aliens are likely to become dominant, resulting in a decline of native species. The use of the FAIL to determine the category is illustrated in Table 14.1.

Table 14.1 Determination of the resulting fish category for the different flow scenarios

Resource Unit	IFR 10.5	IFR10.6	IFR 10.7	IFR 10.8
Native species richness	4	4	2	2
Presence of native intolerant species	1	1	0	0
Abundance of native species	4	4	2	2
Frequency of occurrence of native	3	3	1	1
Health/condition of native and introduced species	4	4	1	1
Presence of introduced fish species	2	2	1	1
In-stream habitat modification	4	4	2	2
TOTAL FISH SCORE	22	22	9	9
%	62.9	62.9	25.7	25.7
FISH ASSEMBLAGE CATEGORY	C	C	E	E

Aquatic Invertebrates (C)

Dry season: Scenario 5 lies between the C (B/C for invertebrates) and D (C/D for invertebrates) lines. Category C. Invertebrates will be well catered for by the stress conditions for the critical components.

Wet season: Scenario 5 at low stress situations is a much better condition than the C line. Category B.

Ecostatus (C)

Compared to the C IFR component categories, two categories are worse, i.e. fish and aquatic invertebrates by half a category. The stress profiles are very similar, with Sc 5 being slightly worse during the dry season (compared to the C profile) and better in the wet season. The decision was made that this scenario still falls within the C Ecostatus.

14.5 Sc 6 CONSEQUENCES**Water quality (B)**

See Sc 5.

Geomorphology (C)

See Sc 5.

Riparian Vegetation (C/D)

See Sc 5.

Fish (C/D)

See Sc 5.

Aquatic Invertebrates (C)

Dry season: Scenario 6 closely follows the D (C/D for invertebrates) lines. Category C/D.

Wet season: Scenario 6 follows the C line (B/C for invertebrates) especially during stress conditions > 3.5. Category B/C.

Overall category: Category C.

Ecostatus (C/D)

The distribution in the components is exactly the same as for Sc 5. The stress profiles are however slightly worse than Sc 5 and this therefore warrants a C/D Ecostatus.

14.6 Sc 7 CONSEQUENCES

Water quality (B)

Scenarios 7 (present) and 8 are not expected to result in changes to the present water quality status of the system, i.e. the ERC will be met under all scenarios.

Geomorphology (C)

See Sc 5.

Riparian Vegetation (D)

Dry season, critical stress of 7: Greater levels of stress for a longer duration during winter. May lead to thinning of grass and sedge mats. Possibly drop half a category.

Dry season, critical stress of 8: Significantly extended stress levels of 9, for longer periods, may lead to thinning of grass and sedge mats for up to 95% of the time. Likely to drop half a category to D during winter.

Wet season, critical stress of 5: Extended stress of 8 - 9 during drought periods in summer (up to 15% of the time). Extended die off of older individuals. This would ensure good resilience tempering and maintain vigour of clumps. Maintain category.

Fish (E)

A loss of inundated marginal areas and riffle spawning habitat for much of the wet season occurs. Dry season refuges are severely limited, with overcrowding, disease and poor condition becoming a major problem. Fish assemblage is confined to tolerant species, but these are also under severe stress. The use of the FAIL to determine the category is illustrated in Table 14.1.

Aquatic Invertebrates (E)

Dry season: For >95% of the time, the invertebrates will suffer stress of 6 - 9, thus having little acceptable habitat. Category E.

Wet season: During drought years/times will be substantially more stressed than the D (C/D for invertebrates) category. Category D.

Overall category: Category E.

Ecostatus (E)

Apart from geomorphology, the situation is considerably worse than the D IFR categories. Fish and aquatic invertebrates have both dropped by more than a category to below a D and this warrants an Ecostatus of an E. The Sc 7 stress profile is considerably worse than the D IFR profile.

14.7 Sc 8 CONSEQUENCES

Water quality (B)

See Sc 7. For scenario 8, SRP conditions may worsen slightly, but probably not enough to change category, because of the high flows related to the wet season ((DWAFF, 2004b (DWAFF Report No. PBV000-00-10307)).

Geomorphology (D)

This scenario illustrates flows lower than the IFR requirements, however if the flood requirements are met there is an unlikely drop in category. Thus there is a reduction of category from C to D.

Riparian Vegetation (D/E)

Dry season, critical stress of 7: Greater levels of stress for a longer duration during winter. This may lead to thinning of grass and sedge mats. Possibly drop half a category.

Dry season, critical stress of 8: Significantly extended stress levels of 9, for longer periods, may lead to thinning of grass and sedge mats for up to 95% of the time. Likely to drop half a category to D during winter.

Wet season, critical stress of 5: Extended stress 8 - 9 during drought periods in summer (up to 35% of the time). Leads to thinning and reduction in the category.

Fish (E)

The rationale is the same as for Sc 7. Category E. The use of the FAIL to determine the category is illustrated in Table 14.1.

Aquatic Invertebrates (E)

Dry season: For > 95% of the time, the invertebrates will suffer stress of 6 - 9, thus having little acceptable habitat. Category E.

Wet season: For 30% of the time in the wet season, there will be no inundated marginal vegetation habitat. Category E.

Overall category: Category E.

























Ecostatus (E)

This scenario represents conditions even worse than Sc 7 and the Ecostatus is therefore also an E.

14.8 COMPARISON OF SCENARIOS

A comparison of the scenarios is illustrated in Table 14.2 below.

Table 14.2 Comparison of the ecological consequences of scenarios – IFR 10

Sc	EC	Worse					Same		
2 	C/D								
3,5,6 	C								
7 	E								
8 	E								

14.9 CONSIDERATION OF NON-FLOW RELATED ISSUES

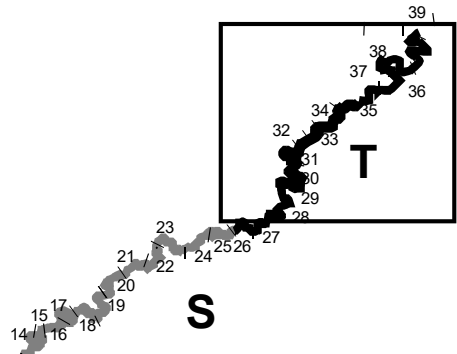
Problems are flow related. Not changes are therefore expected in the Mooi River Ecostatus when considering non-flow related issues.

15 ECOLOGICAL CONSEQUENCES: IFR 11

15.1 SCENARIOS REQUIRING EVALUATION

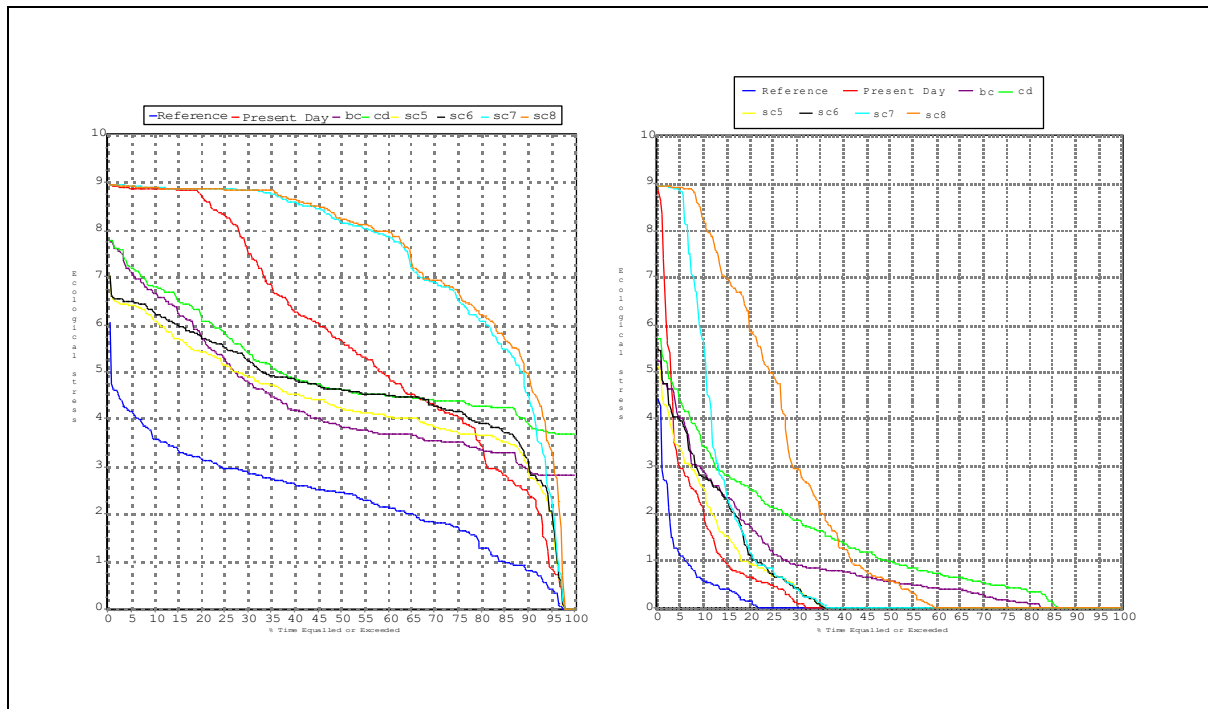
The following scenarios were found to be similar and therefore only Sc 5, 6, 7 and 8 were evaluated.

Note:
Sc 2 = Sc 5
Sc 3 = Sc 6



15.2 SCENARIOS CONVERTED TO STRESS PROFILES

Fig 15.1 Dry (left) and wet (right) season stress profiles



15.3 RESULTING ECs FOR EACH SCENARIO

The resulting EC for each component and for the Ecostatus is provided in Figure 15.2. The PES, long-term resulting trajectory and ERC are also provided for reference purposes. This information was determined during a previous phase in the project and is provided in DWAF, 2003b (DWAF Report No. PBV000-00-10303).

The motivation for each component EC is provided in the sections below.

Fig 15.2 Resulting component status and Ecostatus

COMPONENT	PES	LONG TERM (20 Y)	ERC	DOWN	Sc 5 (2)	Sc 6 (3)	Sc7	Sc 8
WATER QUALITY	A/B	A/B	A/B		A/B	A/B	A/B	A/B
GEOMORPH	C	C	C	D	C	C	C	D
RIPARIAN VEGETATION	C	C	C	D	C	C	E	E/F
FISH	B	B	B	C	B	B/C	E	E/F
AQUATIC INVERTS	B	B	B	C	B	B/C	E	E
ECOSTATUS	B/C	B/C	B/C	C/D	B/C	C	E	E/F

15.4 Sc 5 CONSEQUENCES

Water quality (A/B)

All scenarios will maintain water quality in an A/B category, with SRP conditions improved under scenario 5 in the dry season.

Geomorphology (C)

Wet season flows appear to be higher than requested for the IFR in all scenarios except Sc 8. The site does not have flow-related management uses, therefore conditions are likely to remain the same if the IFR is met or if flow is improved. Scenarios 5 and 6 will keep the category a C.

Riparian Vegetation (C)

Juncus sp., *Dry season*: Essentially similar to the existing category (C), with marginally higher stresses throughout. Existing clumps of *Juncus* will be maintained. Maintain the C category.

Juncus sp., *Wet season*: Slightly lower stresses at times, however not for periods long enough to result in improved status.

Fish (B)

The entire complement of native species are able to survive and breed in dry and wet seasons respectively. There is a slight reduction in habitat for riffle-breeding species, but only for short periods. Category B. The use of the FAIL to determine the category is illustrated in Table 15.1.

Table 15.1 Determination of the resulting fish category for the different flow scenarios

Resource Unit	IFR 10.5	IFR10.6	IFR 10.7	IFR 10.8
Native species richness	4	4	2	1
Presence of native intolerant species	4	4	0	0
Abundance of native species	4	4	2	1
Frequency of occurrence of native	4	4	2	2
Health/condition of native and introduced species	5	5	1	1
Presence of introduced fish species	3	3	1	1
In-stream habitat modification	4	4	2	1
TOTAL FISH SCORE	28	28	10	7
%	80.0	80.0	28.6	20.0
FISH ASSEMBLAGE CATEGORY	B (B/C)	B (B/C)	E	E

Aquatic Invertebrates (B)

Dry season: This scenario lies between the B/C (B for invertebrates) and C/D (C for invertebrates) curves. Category B.

Wet season: Stresses closely follow the B/C (B for invertebrates) line, especially at stresses > 2.5 which are most significant. Category B.

Overall category: Category B.

Ecostatus (B/C)

The component spread of categories is the same for the B/C (recommended ERC) and for Sc 5. The Ecostatus will therefore stay a B/C.

15.5 Sc 6 CONSEQUENCES**Water quality (A/B)**

See Sc 5.

Geomorphology (C)

See Sc 5.

Riparian Vegetation (C)***Juncus* sp.**

Dry season: Marginally higher stresses in winter for 60% of the time (4.5) as opposed to existing (3.5). This may lead to a thinning of clumps during winter, but may not lead to a drop in the category.

Wet season: Similar to dry season rationale.

Fish (B/C)

As for Sc 5, but with increased loss of habitat. The category is a B/C. The use of the FAIL to determine the category is illustrated in Table 15.1.

Aquatic Invertebrates (B/C)

Dry season: This scenario closely follows the C/D (C for invertebrates) category, except during high stress (> 5) when the scenario is less stressful than the C/D curve. Category C.

Wet season: Closely follows the B/C (B for invertebrates) category. Therefore category B.

Overall category: Category B/C

Ecostatus (C)

Both fish and invertebrates have decreased by half a category versus to Sc 5. The stress levels are also marginally worse and the decision was that this therefore warrants a half a category decrease from Sc 5, i.e. a category C.

15.6 Sc 7 CONSEQUENCES

Water quality (A/B)

See Sc 5.

Geomorphology (C)

See Sc 5.

Riparian Vegetation (E)

Juncus sp.

Dry season, critical stress: Significantly higher stresses for longer duration than for the recommended category. There is also much higher maximum stress (9 vs. 8) for 30% of the time. This may lead to the thinning of clumps during winter, but may not lead to a decrease in category.

Wet season, critical stress: There are higher stress levels during summer droughts (9 as opposed to 6) for 10% of the time. This will lead to a thinning of older plants and plants on lower terraces. A decrease in category to D/E.

Fish (E)

Extinction of riffle-dwelling and intolerant species and the minimal breeding success of pool species during the wet season occur. Tolerant species suffer severe stress in pools during the dry season. There is an increase in abundances of alien species. The use of the FAIL to determine the category is illustrated in Table 15.1.

Aquatic Invertebrates (E)

Dry season: Stresses of > 5 will occur for 90% of the time, meaning that rheophilic species will be at severe risk. Category E.

Wet season: For 10% of the wet season, stress > 6 meaning that vegetation habitat will be minimal and in a worse condition than the C/D category, but for the rest of the seasons is better than B/C. Category C/D.

Overall category: Category E.

Ecostatus (E)

Three categories have dropped by more than one category (fish and invertebrates from a B/C to an E) to an unacceptable ecological condition, i.e. an E category. This provides sufficient motivation for an Ecostatus of an E. This is also a logical trend from the upstream IFR 10 site. The stress profile for Sc 7 confirms the Ecostatus as there is significantly more stress than the C/D IFR profile.

15.7 Sc 8 CONSEQUENCES

Water quality (A/B)

See Sc 5.

Geomorphology (D)

Sc 8 will move the category to a D, as this flow is below the requested IFR for 60% of the time. This will lead to increased sedimentation.

Riparian Vegetation (E/F)

Dry season, critical stress: Significantly higher stresses for longer durations. There is a much higher maximum stress (9 as against 8) for 30% of the time. This will lead to thinning of clumps, especially on low marginal terraces, and a decrease in category below D, to possibly E or E/F.

Wet season, critical stress: Much higher maximum stress levels during droughts and throughout summer, resulting in significant thinning of clumps and a decrease in category to an E.

Fish (E/F)

The explanation is as for Sc 7, but closer to extinction of all native species from the system, Category E/F. The use of the FAIL to determine the category is illustrated in Table 15.1.

Aquatic Invertebrates (E)

Dry season: Stresses of > 5 will occur for 90% of the time, meaning that rheophilic species will be at severe risk. Category E.

Wet season: Stress levels are exceptionally high with loss of suitable habitats for >20% of the time. Category D.

























Ecostatus (E/F)

The situation is even worse than for Sc 7, therefore the Ecostatus have dropped by half a category to an E/F.

15.8 COMPARISON OF SCENARIOS

A comparison of the scenarios is illustrated in Table 15.2 below.

Table 15.2 Comparison of the ecological consequences of scenarios – IFR 11

Sc	EC	Worse				Same				
2, 5 	B/C									
3, 6 	C									
7 	E									
8 	E/F									

15.9 CONSIDERATION OF NON-FLOW RELATED ISSUES

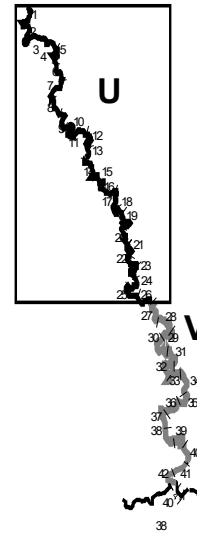
Problems are flow related. No changes are therefore expected in the Mooi River Ecostatus when considering non-flow related issues.

16 ECOLOGICAL CONSEQUENCES: IFR 13

16.1 SCENARIOS REQUIRING EVALUATION

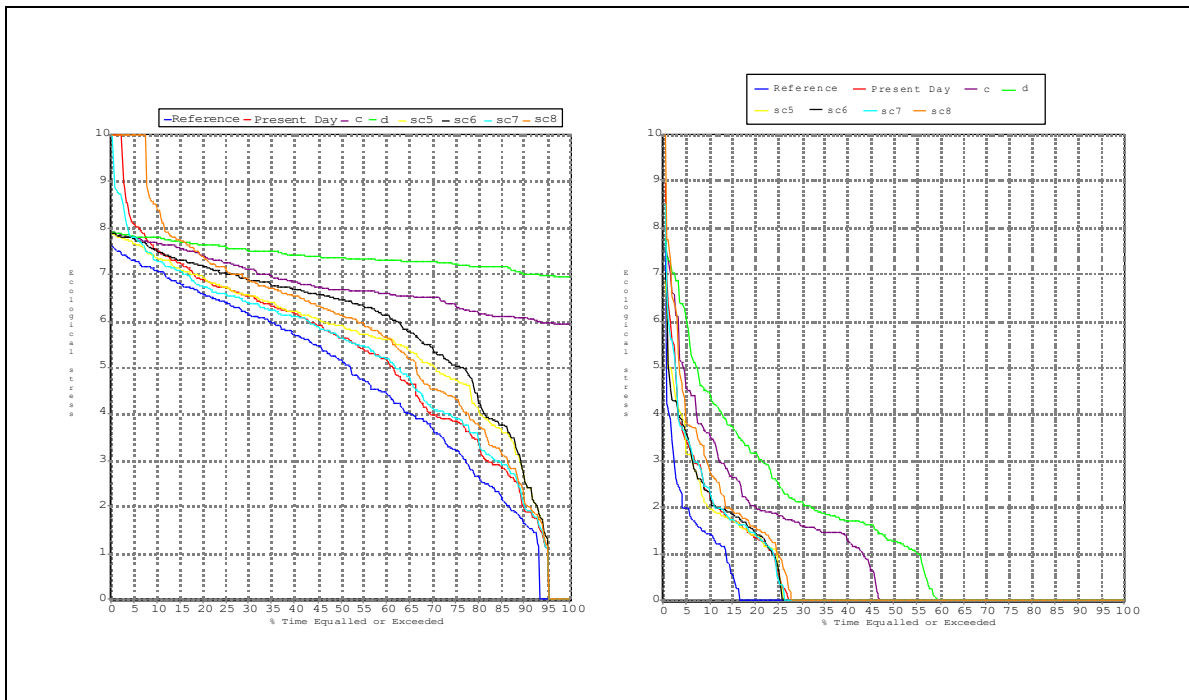
The following scenarios were found to be similar and therefore only Sc 5, 7 and 8 were evaluated.

Note:
Sc 2 = Sc 5
Sc 3 = Sc 6



16.2 SCENARIOS CONVERTED TO STRESS PROFILES

Fig 16.1 Dry (left) and wet (right) season stress profiles



16.3 RESULTING ECs FOR EACH SCENARIO

The resulting EC for each component and for the Ecostatus is provided in Figure 16.2. The PES, long-term resulting trajectory and ERC are also provided for reference purposes. This information was determined during a previous phase in the project and is provided in DWAF, 2003b (DWAF Report No. PBV000-00-10303).

The motivation for each component EC is provided in the sections below.

Fig 16.2 Resulting component status and Ecstatus

COMPONENT	PES	LONG TERM (20 Y)	ERC	Sc 5 (2)	Sc 6 (3)	Sc 7	Sc 8
WATER QUALITY	D	D/E	C	D	D	D	D/E
GEOMORPH	D/E	D/E	D	D	D	D	D
RIPARIAN VEGETATION	D/E	E	D	B	B/C	B	C
FISH	C	C/D	C	B	B/C	B/C	C/D
AQUATIC INVERTS	C/D	D	C/D	B	B/C	B	E
ECOSTATUS	D	D/E	D	B	B/C	B/C	D

16.4 Sc 5 CONSEQUENCES

Water quality (D)

Under scenarios 5, 6 and 7 conditions are expected to remain as at present, i.e. category D according to the revised methods of DWAF (2002). The water quality Reserve category of a C will therefore not be met under any scenarios unless sulphate pollution and coalmine drainage in this catchment is addressed.

Geomorphology (D)

Wet season flows are higher than those in the requested IFR. This site can be improved by flow. Management of flow could improve the category for all reaches to a C.

Riparian Vegetation (B)

Setaria

Dry season, critical stress: Significant reductions in overall stress due to increased availability of water. This will maintain existing growth and promote new *Setaria* clumps in marginal areas. High stress levels present in winter. Droughts are maintained, therefore an increase in category to a B.

Wet season, critical stress: Decreased stress levels: generally particularly during high flows. This would result in the maintenance of existing clumps and widening of the marginal zone into the lower terraces. Therefore an improved to category B.

Fish (B)

The assemblage is dominated by native species; adequate spawning habitat in wet season and pool refuge in dry season exists. Intolerant species are able to survive all year round. The use of the FAIL to determine the category is illustrated in Table 16.1.

Table 16.1 Determination of the resulting fish category for the different flow scenarios

Resource Unit	IFR 11.5	IFR11.6	IFR 11.7	IFR 11.8
Native species richness	4	4	4	3
Presence of native intolerant species	4	4	4	3
Abundance of native species	5	4	4	3
Frequency of occurrence of native	4	4	4	3
Health/condition of native and introduced species	4	4	4	3
Presence of introduced fish species	3	3	3	3
In-stream habitat modification	4	4	4	3
TOTAL FISH SCORE	28	27	27	21
%	80.0	77.1	77.1	60.0
FISH ASSEMBLAGE CATEGORY	B	C	C	C

Aquatic Invertebrates (B)

Dry season: If floods were included in the C (B/C invertebrates) evaluation, this would bring this curve to Sc 6. Sc 5 is better than that, with lower stress. Category B.

Wet season: Stress levels are low and closer to natural than the C (B/C invertebrates) category. Category B.

Ecostatus (B)

All categories (apart from water quality which is maintained) have improved significantly from the Recommended ERC. Three of the components are in a B category which therefore warrants a B Ecostatus.

16.5 Sc 6 CONSEQUENCES**Water quality (D)**

See Sc 5.

Geomorphology (D)

See Sc 5.

Riparian Vegetation (B/C)

Dry season: Reduced stress levels will maintain existing grass clumps and promote new growth on lower terraces.

Wet season: Decreased stress levels: generally particularly during high flows. This would result in the maintenance of existing clumps and widening of the marginal zone into the lower terraces. Therefore an improvement in category to B.

Overall category: Category B/C.

Fish (B/C)

As for Sc5 and Sc7. Slightly less dry refuge and wet spawning habitat is available. The use of the FAIL to determine the category is illustrated in Table 16.1.

Aquatic Invertebrates (B/C)

Dry season: If floods are included in the C (B/C invertebrates) category, this makes it very similar in nature to this scenario. Category B/C.

Wet season: As for Sc 5.

Overall category: Category B/C.

Ecostatus (B/C)

Sc 6 is still considerably better than the Recommended ERC, however instead of increasing categories to a B, the same components have increased to a B/C. Instead of a B Ecostatus, this then results in a B/C Ecostatus.

16.6 Sc 7 CONSEQUENCES**Water quality (D)**

See Sc 5.

Geomorphology (D)

See Sc 5.

Riparian Vegetation (B)

Dry season, critical stress: Increased maximum stress levels (10 vs. 8) for 4% of the time, resulting in loss and thinning of clumps during winter droughts. This will promote resilience. Otherwise, it is similar to Sc 5. Improve to a category B.

Wet season, critical stress: Decreased stress levels except during summer droughts, however for 1% of the time stresses of 10 are reached and will temper resilience of vegetation clumps. Improve to category B.

Fish (B/C)

See Sc 6.

Aquatic Invertebrates (B)

Dry season: During low stress periods Sc 7 is less stressful than Sc 5, but it has a high stress dry season drought 2 - 3% of the time. Category B.

Wet season: See Sc 5. Category B.

Overall category: Category B.

Ecostatus (B/C)

Sc 7 represents better conditions than Sc 6, but only marginally. It is very similar to Sc 5, with only one component dropping from the B to a B/C status. The profiles indicate a worse drought situation associated with Sc 7 than for Sc 5 and this therefore resulted in an Ecostatus of a B/C, rather than a B (as for Sc 5).

16.7 Sc 8 CONSEQUENCES**Water quality (D/E)**

As there are times of no flow under scenario 8, conditions would be expected to drop half a category to a D/E – (according to the revised methods of DWAF (2002)).

Geomorphology (D)

See Sc 5.

Riparian Vegetation (C)

Dry season, critical stress: Essentially similar to 6, except that 10% of the time there are stresses of up to 10 which temper resistance. An improvement to a category C overall, but also will result in increased die-off. Therefore a category C.

Wet season, critical stress: Decreased stress levels are present except during summer droughts, however for 1% of the time stresses of 10 are reached and will result in temper resilience of vegetation clumps. Increase to category B.

Overall category: Category C.

Fish (C/D)

A partial loss of refuge during the dry season for intolerant riffle dwellers exists. Perhaps a loss of a few intolerant and/or riffle-dwelling species for 15 - 20% of the time during low flows will occur. The use of the FAIL to determine the category is illustrated in Table 16.1.

Aquatic Invertebrates (E)

Dry season: Although much of the season this scenario would be a B, the intense drought (stress > 8) for 12% of the time makes this an unacceptable habitat, as there is no surface water. Category E.

Wet season: This scenario is closer to the C category (B/C invertebrates), but for 1% of the time reaches maximum stress (no surface water). This is unacceptable for a wet season. Category E.
















Ecostatus (D)

This situation is considerably worse than the other scenarios investigated. The spread of component categories are similar to those of the Recommended ERC of a D. The comparison indicates that water quality is half a category worse, riparian vegetation is one category better, fish is half a category worse and aquatic invertebrates 1.5 categories worse. Even though three of the components are worse than those illustrated under the Recommended ERC, only one category falls below a D, i.e. aquatic invertebrates. The decision was made that this does not warrant an Ecostatus below a D and the Ecostatus was set at a D.

16.8 COMPARISON OF SCENARIOS

A comparison of the scenarios is illustrated in Table 16.2 below.

Table 16.2 Comparison of the ecological consequences of scenarios – IFR 13

Sc	EC	Worse			Same		Improved		
2,5 ↑	B								
3, 6, 7 ↑	B/C								
8 ↔	D								

16.9 CONSIDERATION OF NON-FLOW RELATED ISSUES

When considering non-flow related issues (all related to land use) which are unlikely to change, the advantage of improved flows were tempered by the following

- § The vegetation category will drop to a D/E for all scenarios.
- § Water quality is a D for all scenarios and D/E for Sc 8.
- § Inverts will drop to a C/D for all scenarios except Sc 8 which will stay as it is.
- § Fish for Sc 5,6, and 7 will drop to a C and Sc 8 to a D.

The Ecostatus results for the individual scenarios will probably be the following:

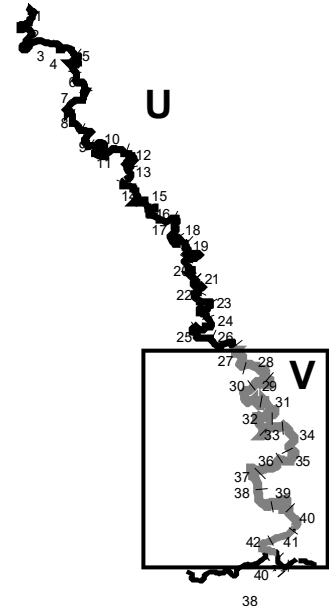
- § Sc 5, 6 and 7: The spread of component categories are similar than those for the D ERC with two components being worse. The Ecostatus is therefore definitely a D.
- § Sc 8. The situation is now considerably worse than for the Recommended ERC and the evaluated Sc 8. It is likely therefore that the Ecostatus would be a D/E.

17 ECOLOGICAL CONSEQUENCES: IFR 14

17.1 SCENARIOS REQUIRING EVALUATION

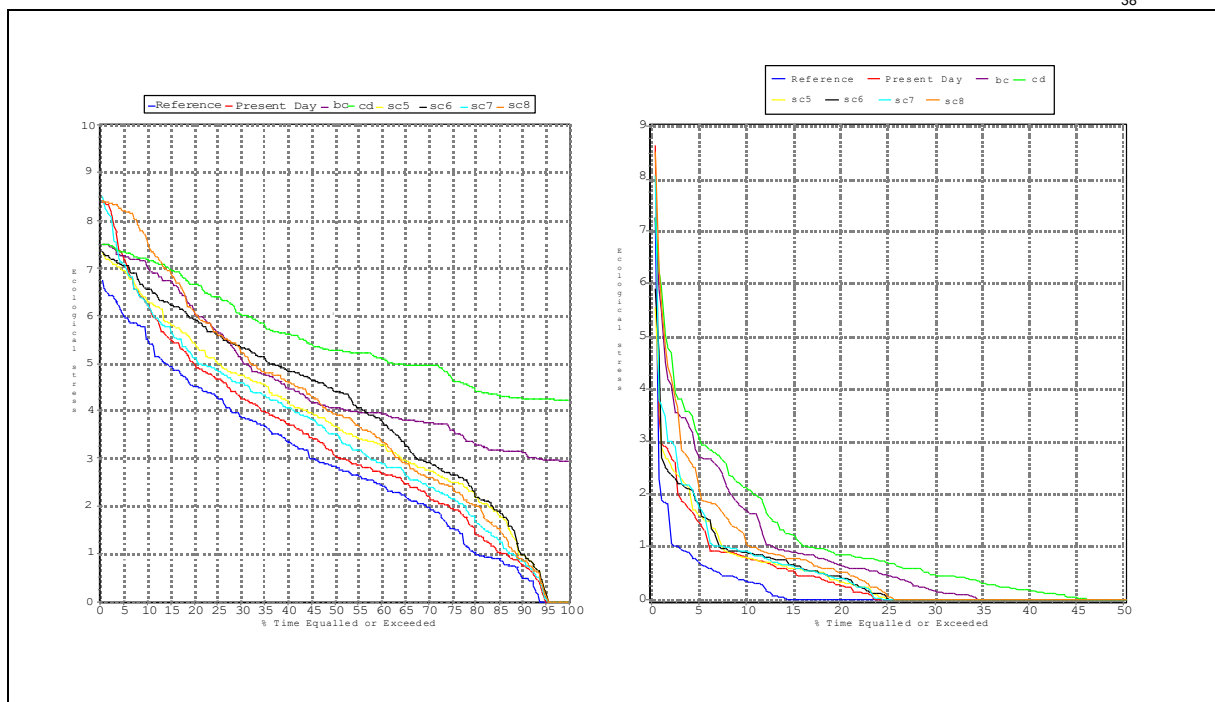
The following scenarios were found to be similar and therefore only Sc 5, 6, 7 and 8 were evaluated.

Note:
Sc 2 = Sc 5
Sc 3 = Sc 6



17.2 SCENARIOS CONVERTED TO STRESS PROFILES

Fig 17.1 Dry (left) and wet (right) season stress profiles



17.3 RESULTING ECs FOR EACH SCENARIO

The resulting EC for each component and for the Ecostatus is provided in Figure 17.2. The PES, long-term resulting trajectory and ERC are also provided for reference purposes. This information was determined during a previous phase in the project and is provided in DWAF, 2003b (DWAF Report No. PBV000-00-10303).

The motivation for each component EC is provided in the sections below.

Fig 17.2 Resulting component status and Ecostatus

COMPONENT	PES	LONG TERM (20 Y)	ERC	DOWN	Sc 5 (2)	Sc 6 (3)	Sc 7	Sc 8
WATER QUALITY	C/D	C/D	C		C/D	C/D	C/D	D
GEOMORPH	B/C	B/C	B/C	C/D	B/C	B/C	B/C	B/C
RIPARIAN VEGETATION	B/C	C	B/C	C/D	B	B/C	B/C	C
FISH	C	C	C	D	B	B	B	D
AQUATIC INVERTS	B	B	B	C	A/B	B	A/B	C
ECOSTATUS	B/C	B/C	B	C/D	B	B/C	B	C

NOTE: The flow regime for the B/C PES and B ERC will be the same as the improvement required is for water quality only.

17.4 Sc 5 CONSEQUENCES

Water quality (C/D)

No water quality modelling was carried out at this site, as there is no nearby monitoring station. An assessment was made based on professional judgement and limited data, and confidence is low.

Present EC is in a C/D category (using the revised methods of DWAF (2002)) due to the high sulphate and nutrient levels seen. During the wet season, all scenarios are equivalent to present EC; no changes are therefore predicted. During the dry season, scenario 5 provides slightly more water, but probably not enough to improve the category, particularly as this is a low confidence site. The quality Reserve category will not be met under any scenario.

Geomorphology (B/C)

Wet season flows appear to be higher than requested for the IFR in all scenarios. The site does not have flow-related management uses, therefore conditions are likely to remain the same if the IFR is met or if flow is improved. Thus the category remains a B/C for all scenarios.

Riparian Vegetation (B)

Juncus sp.

Dry season, critical stress: Decreased stress due to improved water availability which will result in thickening and widening of existing mats. Therefore improve the category.

Wet season, critical stress: Improved water availability with decreased stress. Generally may lead to widening of the marginal zone. Improve category to B.

Overall category: Category B.

Fish (B)

During the wet season there is adequate breeding habitat for all species. During the dry season there is a brief period (10% of the time) of habitat reduction for riffle-dwelling species.

Aquatic Invertebrates (A/B)

Dry season: This scenario lies between natural and the B/C (B for invertebrates) category. Category A/B.

Wet season: This scenario is lies between natural in the B/C (B for invertebrates) category. Category A/B.

Ecostatus (B)

The component categories of this scenario are compared with those of the B/C PES and B ERC (the only change to improve the Ecostatus required an improvement in water quality). Water quality is a lower category and the three biological components are higher. It was however felt that overall this spread of categories does represent an improvement of the B/C PES to a B Ecostatus, even if the water quality ERC is not met. The stress profiles confirm this and indicate that if anything, the only other option would be an A/B category. Sufficient motivation for this is however not available. The Ecostatus of a B was therefore allocated.

17.5 Sc 6 CONSEQUENCES**Water quality (C/D)**

See Sc 5.

Geomorphology (B/C)

See Sc 5.

Riparian Vegetation (B/C)**Juncus sp.**

Dry season, critical stress: Essentially the same as the existing situation therefore maintain existing mats of *Juncus* spp. Maintain category B/C.

Wet season, critical stress: Improved water availability with decreased stress. Generally this may lead to the widening of the marginal zone. Increase category to B.

Overall category: Category B/C.

Fish (B)

See Sc 5.

Aquatic Invertebrates (B)

Dry season: This scenario is close to the B/C line (B for invertebrates) and at high stress levels (>5.5) is better. Category B.

Wet season: Same as for Sc 5. Category A/B/

Overall category: Category B.

Ecostatus (B/C)

The spread of component ERCs is the same as for the PES of a B/C apart from fish that has improved to a B/C. Without the required water quality improvement, the fish improvement alone would not warrant the improvement of the PES of a B/C. The Ecostatus is thus set at a B/C. As the water quality improvement is not flow-related, this can however not be seen as a flow scenario that does not meet the ERC.

17.6 Sc 7 CONSEQUENCES**Water quality (C/D)**

See Sc 5.

Geomorphology (B/C)

See Sc 5.

Riparian Vegetation (B/C)

Dry season: Similar to Sc 5 except that there are more severe winter droughts which will improve vigour and resistance. Thus, maintain category B/C.

Wet season: Similar to Sc 5/6 except with more severe summer drought for < 1% of the time. Maintain category B/C.

Fish (B)

See Sc 5.

Aquatic Invertebrates (A/B)

See Sc 5.

Ecostatus (B)

As the Sc 7 profile is better than the Sc 5 profile, it has to be the same category or better. Sc 5 is a B and, even though it is better it is only marginally so and does therefore not warrant an increase in category.

17.7 Sc 8 CONSEQUENCES**Water quality (D)**

During the dry season scenario 8 will probably elevate the concentrations of sulphate and nutrients (particularly periphyton), as periods of virtually no flow occur, thereby changing the water quality to a D category.

Geomorphology (B/C)

See Sc 5.

Riparian Vegetation (C)

Dry season, critical stress: Similar to the present EC except for more severe winter droughts for up to 10% of the time, at stress 8. There is a reduction or loss of clumps in the short or medium term. Decrease in category to C.

Wet season, critical stress: An improvement in general stress exists except during summer drought, where stresses reach 8 for >1% of the time. Maintain existing clumps with some losses in summer. Possibly drop half a category.

Overall category: Category C.

Fish (D)

Wet season same as Sc 7. During the dry season the extended period of low or no flow may see the exclusion of riffle dwelling species from this reach. The use of the FAIL to determine the category is illustrated in Table 16.1.

Aquatic Invertebrates (C)

Dry season: This scenario is generally better than a B category, with the exception of 15% of the time when stress is >7. Only hardy rheophiles will survive and this will result in a C category.

Wet season: Better than the B/C category but greater drought stress resulting in a B category.

Overall category: Category C.

























Ecostatus (C)

The spread of categories are compared to those for the C/D IFR. Geomorphology is still higher and vegetation half a category higher. The other components are the same with water quality decreasing to a C/D. The improvement in geomorphology probably warrants a higher Ecostatus than the C/D, therefore the allocation of a C category to the Ecostatus.

17.8 COMPARISON OF SCENARIOS

A comparison of the scenarios is illustrated in Table 17.1 below.

Table 17.1 Comparison of the ecological consequences of scenarios – IFR 14

Sc	EC	Worse			Same			Improved			
2, 5 	B										
3, 6 	B/C										
7 	B										
8 	C										

17.9 CONSIDERATION OF NON-FLOW RELATED ISSUES

When considering non-flow related issues which are unlikely to change, the advantage of improved flows were tempered by the following

- \$ Water quality is a C/D for all scenarios 5, 6 and 7.
- \$ Fish will drop to a C for all scenarios except Sc 8 which will stay as it is.
- \$ Invertebrates for Sc 5 and 7 will drop to a B.

The Ecstatus results for the individual scenarios will probably be the following:

- Sc 5 and 7: The spread of component categories are similar than those for the B/C ERC and the Ecstatus will drop from a B to a B/C.
- Sc 6 could possible drop to a C, although this is low confidence.

18 SCENARIO 9 ANALYSIS

18.1 NECESSITY FOR AN ADDITIONAL SCENARIO

During the analysis of the results generated at each IFR site, it became obvious that even Sc 6, which impacts least on the yield (apart from Sc 7 and Sc 8 which are not realistic scenarios and do not include any Reserves) and has a minimal impact on the ecology, still provides more water at various IFR sites. (See chapter 19 for the summary of the impacts). It was therefore decided to create an additional scenario to attempt to optimise the existing Sc 6 and thereby decrease the impact on yield of Sc 6. The new scenario is referred to as Sc 9 and the ecological implications of this scenario must be investigated.

18.2 DESCRIPTION OF Sc 9

Scenario 9 was devised during a meeting consisting of the WRYM modellers and key members of the Reserve team. Sc 6 was used as a baseline and the changes that are required are illustrated in Table 18.1.

Table 18.1 Sc 6 changes required to create Sc 9

IFR site	Change 1	Change 2	Comment
IFR 1	-	-	WRP change the rule at IFR 1 and supply more realistically – no 2 cumec release, but supply users according to firm demand.
IFR 2	Delete 80m ³ /s flood		All other floods are smaller than 36m ³ /s which is the outlet capacity of the dam.
IFR 3	Run as for Sc 5, i.e. at ERC of C/D	Delete two 32m ³ /s	For decision-making purposes, the economic consequences of both the C/D and D ERCs must be investigated.
IFR 4	Delete three 90m ³ /s		
IFR 5	Delete 30, 45, and 30m ³ /s	Change maintenance fresh of 30 to 16	Outlet capacity of Wagendrift is 8 m ³ /s.
IFR 6	Same principles as above		
IFR 7	Delete two 14m ³ /s		
IFR 8	Delete 28, 15, and 28 m ³ /s		
IFR 9	Delete 170, 95, and 50m ³ /s		
IFR 10	Run as for Sc 5 (ERC C rather than D)	Delete all 25 and 15 m ³ /s under floods	
IFR 11	Run as for Sc 5 (ERC C rather than D)	Delete all 28 m ³ /s under floods	
IFR 12	Same flood rules as IFR 11		This was not done as Sc 5 as the ERC is lower than the upstream sites.
IFR 13	Delete 60, 60, and 25 m ³ /s		
IFR 14	Delete 80, and 50m ³ /s		
Zaaihoek	Delete 25, 25, and 10m ³ /s		
Chelmsford	Ditto		
IFR 15	Delete 110, 110, and 150m ³ /s		
IFR 16	Same principle as IFR 15		
A check must be made that after the removal of these high flows, that the remaining highest flood falls within the same month right through the system. The additional remaining floods must also be checked to ensure that they match throughout the system.			

18.3 ECOLOGICAL EVALUATION

18.3.1 Process

The Sc 6 IFR output was adjusted accordingly and the WRYM was run to test Sc 9. The results were supplied at each IFR site and converted to stress profiles. The Sc 9 stress profile was analysed using the stress profiles, which, together with their respective resulting categories, were used to provide a guide for the attachment of the Ecostatus to Sc 9. The full range of specialists were therefore not involved. At any stage where the Ecostatus could not be determined, the results were provided to specialists for the individual component information.

18.3.2 Ecological consequences of Sc 9

As this process was undertaken after the specialist meeting, and after all the documentation of that process, the Sc 9 evaluation is not included in all the graphs and tables provided earlier.

No discernable change to the ERCs could be detected when the stress was evaluated. This is probably understandable as the major changes were on high flows that cannot be interpreted through stress profiles. Slight changes in stress were detected during the wet season, but not significant enough to warrant a category change. It must however be emphasized that interpretation of high flow scenarios under any circumstances and even with the relevant specialists present a problem as the output is provide as monthly flows.

The results were therefore that all the sites resulted in the same category as Sc 6 apart from IFR 3, 10 and 11 (which were modelled as Sc 5) were the same category as Sc 5.

19 CONCLUSIONS

The ecological consequences have been provided on an IFR site by site basis for each scenario. A summary of the Ecospecs is provided in Figure 19.1. To facilitate decision-making, the scenarios must now be analysed for the system. Two processes were followed as follows:

- For each Sc, the number of IFR sites at which the recommended ERC has been maintained, improved, or worse has been summed.
- Multi-criteria analysis (MCA): This is an umbrella term for a wide range of techniques that explicitly include multiple criteria in the evaluation of alternatives or scenarios. In essence they all require that criteria are identified, alternatives are evaluated on the basis of each of these criteria, and that the separate evaluations are aggregated in some way and to greater or lesser degrees.

19.1 ANALYSIS OF IFR SITES AT WHICH THE RECOMMENDED ERCs HAVE BEEN ACHIEVED

The results of the analysis are provided in Table 19.1 below.

Table 19.1 Results of IFR sites at which the recommended ERCs have been achieved

Scenarios	Better*	%	Same^{&}	%	Worse[#]	%
Sc 2	8	57	5	36	1 (IFR 4 ¹)	7
Sc 3	7	50	3	21	4 (IFR 3,4,10,11)	29
Sc 5	7	50	6	43	1 (IFR 4)	7
Sc 6	1	7	5	36	4 (IFR 3,4,10,11)	29
Sc 7	5	36	2	14	9	64
Sc 8	3	21	1	7	12	86
Sc 9	5	36	8	57	1 (IFR 4)	7

* Amount of IFR sites better than the ERC.

& Amount of IFR sites the same as for the recommended ERC.

Amount of IFR sites worse than the recommended ERC.

















¹ IFR 4 in all cases do not meet the recommended ERC which in this case is an improvement of the PES. However, for Sc 2,3,5,6 and 9 it DOES meet the PES.

It is important to understand that a scenario that results in a BETTER ERC than the recommended ERC is not necessarily the desired result. A better ERC is not required as it is highly likely that it can be achieved with only flow changes and the importance of the system did not warrant this improvement. The recommended scenario should be realistic if at all possible. Therefore, if one can provide for the ecological requirements (i.e. the recommended ERC) as well as not disadvantage the users of the system, this would be the most realistic scenario.



Scenario 2, 5 and 9 fails (i.e. does not meet the recommended ERC) at only one IFR site, i.e. IFR 4. Scenario 9 is the only scenario of the three which does not negatively impact on the users and as the recommended ERC is achieved at all the other IFR sites, this will be the ecological recommendation.

A summary of the results is provided below.

Fig 19.1 Summary of results

IFR Site	PES	ERC		2	3	5	6	7	8	9
THUKELA RIVER										
1	D	D		C/D	C/D	 C/D	C/D	D	 E	C/D
2	C	C		B	B	B/C	B/C	 C	 D	B/C
4	B/C	B		 B/C	 B/C	 B/C	 B/C	 D	 D	B/C
9	D	D		C	C	C	C	C/D	C/D	C
15	C	C		 C	 C	 C	 C	 C/D	 C/D	C
16	C/D	C/D		C	C	C/D	C/D	D	D	C/D
ESTUARY	C+	C+		C+	C+	C+	C+	C+	C-	C+

 Flag implies that one of the component ERC will be below a D, i.e. unacceptable.

IFR Site	PES	ERC		2	3	5	6	7	8	9
LITTLE THUKELA RIVER										
3	C/D	C/D		C/D	D	C/D	D	F	F	C/D
BUSHMANS RIVER										
5	B/C	B/C		 A/B	B	 A/B	B	C	C	B
SUNDAYS RIVER										
7	B/C	B/C		B	B/C	B	B/C	C	C	B/C
8	D	D		D	D	D	D	E	E	D

IFR Site	PES	ERC		2	3	5	6	7	8	9
MOOI RIVER										
10	C	C		C	C/D	C	C/D	E	E	C
11	B/C	B/C		B/C	C	B/C	C	E	E/F	B/C
BUFFALO RIVER										
13	D	D		B	B/C	B	B/C	B/C	D	B/C
14	B/C	B/C *		B	B/C	B	B/C	B	C	B/C

* The ERC is actually a B but this requires only improvement in water quality. The evaluation of changed flows are therefore done against the B/C rather as well as knowing what the water quality consequence would be.

19.2 RESULTS OF THE MCDA

A number of conclusions can be drawn from the Multi-criteria analysis to compare the scenarios from the point of view of the overall river system:

- Scenario 2 is best overall and scenario 8 is worse overall.
- There are two groups of scenarios. Scenarios 2, 5, 9, 3 and 6 formed one group which had similar scores and ranked in that order for all the tests performed (Figure 19.1). These scenarios were distinctly better than and separate from the second group (scenarios 7 and 8).
- There is no clear preference of scenario 2 over scenario 5, of scenario 5 over scenario 9 or of scenario 3 over scenario 6. However, scenario 2 is clearly better than scenario 6.

The scenario analysis showed that the resultant scores and rank order of the scenarios was insensitive to the assumptions regarding the conversion from the alphabetic ERC category to a score, and the weights given to the sites (Figure 19.2 and Table 19.1).

Fig 19.2 Overall status of the river for the different scenarios under the four different assumptions described in the text. (Note that assumption 2 leads to scores on a different scale to those of assumption 1, but that the scales are essentially arbitrary).

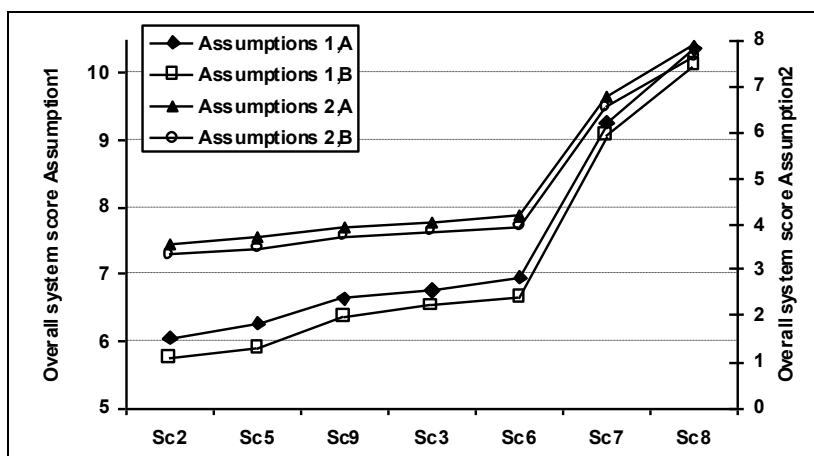


Table 19.2 Overall status of the river for the different scenarios under the four different assumptions described in the text

	Score							Rank						
	Sc2	Sc5	Sc9	Sc3	Sc6	Sc7	Sc8	Sc2	Sc5	Sc9	Sc3	Sc6	Sc7	Sc8
Assumptions 1 and A	6.1	6.3	6.7	6.8	7.0	9.3	10.3	1	2	3	4	5	6	7
Assumptions 1 and B	5.8	5.9	6.4	6.5	6.7	9.1	10.1	1	2	3	4	5	6	7
Assumptions 2 and A	3.5	3.7	3.9	4.0	4.2	6.8	7.9	1	2	3	4	5	6	7
Assumptions 2 and B	3.3	3.5	3.7	3.8	4.0	6.6	7.6	1	2	3	4	5	6	7

19.3 CONCLUSIONS

The MCA described under 19.2 recommends scenario 2 as the MCA analysis assumed that the situation which results in an ERC better than the recommended is a better situation. If this was not the case and the scenarios resulting in better ERCs (than recommended) were penalised, the results would be the same as the analysis undertaken under 19.1. The MCA was undertaken as an experimental analysis during this specialist meeting and various adjustments could therefore not be undertaken.

The recommendation from an ecological viewpoint is therefore that scenario 9 be implemented. Although scenario 9 (and all the other scenarios) does not meet the recommended ERC at the IFR 4, it still meets the PES. The river at IFR 4 will therefore not degrade beyond the PES. There has also been some indication that the PES might have been established as a higher category than necessary and any further work to address the IFR 4 issue should firstly address this issue.

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