water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF WATER AND SANITATION
CHIEF DIRECTORATE: WATER ECOSYSTEMS

THE DETERMINATION OF WATER RESOURCE CLASSES AND ASSOCIATED RESOURCE QUALITY OBJECTIVES IN THE INKOMATI WATER MANAGEMENT AREA









SUPPORTING INFORMATION ON ECOLOGICAL CONSEQUENCES OF OPERATIONAL SCENARIOS

Report Number: RDM/WMA05/00/CON/CLA/0314

SEPTEMBER 2014

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DEPARTMENT OF WATER AND SANITATION
CHIEF DIRECTORATE: RESOURCE DIRECTED MEASURES

THE DETERMINATION OF WATER RESOURCE CLASSES AND ASSOCIATED RESOURCE QUALITY OBJECTIVES IN THE INKOMATI WATER MANAGEMENT AREA

SUPPORTING INFORMTION ON ECOLOGICAL CONSEQUENCES OF OPERATIONAL SCENARIOS

Report Number: RDM/WMA5/00/CON/CLA/0314

Approved for IWR Water Resources by:

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DEPARTMENT OF WATER AND SANITATION (DWS)

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EXECUTIVE SUMMARY

BACKGROUND

The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) initiated a study during 2013 for the provision of professional services to undertake the determination of water resource classes and associated Resource Quality Objectives (RQOs) in the Inkomati WMA. IWR Water Resources was appointed as the Professional Service Provider (PSP) to undertake this study. This study entails Classification and setting of RQOs. Embedded in the National Water Resources Classification System (NWRCS) is the determination of the Reserve. Each of these three processes consists of distinctive steps which overlap and integrated steps were therefore designed and are outlined below.

Step	Description
1	Delineate the units of analysis and Resource Units, and describe the status quo of the water resource(s).
2	Initiation of stakeholder process and catchment visioning.
3	Quantify the Ecological Water Requirements and changes in non-water quality ecosystem goods, services and attributes.
4	**Identify and evaluate scenarios within the integrated water resource management process.**
5	Develop draft Water Resource Classes and test with stakeholders.
6	Develop draft RQOs and numerical limits.
7	Gazette and implement the class configuration and RQOs.

This report forms ***part*** of the outcomes of Step 4 (red above) within the integrated approach (DWA, 2012). The objective of this task was to provide the scenario analysis, assumptions and results and document the consequences of the scenarios for the various components under Task D4 which are provided as two report volumes.

STUDY AREA

The study area comprises the Komati, Crocodile East and Sabie-Sand rivers. These three major tributaries of the international Incomati River Basin are operated largely independently of each other. The Komati River rises in South Africa and flows into Swaziland, then re-enters South Africa where it is joined by the Crocodile River at the border with Mozambique, before flowing into Mozambique as the Incomati River. The Kruger National Park (KNP) is partially located in the Sabie and Crocodile catchments. The Crocodile River is located between the Komati and Sabie rivers. The Crocodile River joins the Komati River just before the border with Mozambique to form the Incomati River. The Sabie River catchment lies in the north of the Inkomati WMA, entering Mozambique after flowing through the Kruger National Park. Once in Mozambique, the Sabie joins the Komati River. The Sabie River catchment is considered the most pristine of the six river catchments that cross over from South Africa to Mozambique (DWA, 2013a).

RESULTS

The ecological consequences per EWR site are summarised in the table below.

Summary of the detailed ecological consequences determined for Sabie, Sand, Crocodile and Komati Rivers

EWR S3 (SABIE RIVER)

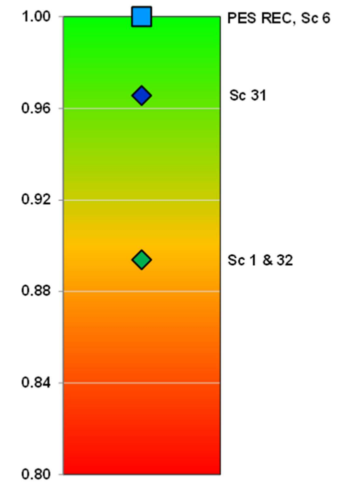
Ecological consequences as ECs

Component	PES & REC	Sc 1	Sc 31	Sc 32	Sc 6
Physico chemical	B	C	B	C	B
Geomorphology	B	B	B	B	B
Fish	B	C	B/C	C	B
Invertebrates	B	C	B	C	B
Riparian vegetation	A/B	B	B	B	A/B
EcoStatus	A/B	B/C	B	B/C	A/B

Ecological consequences

Increased stress during the dry season result in water quality degradation as well as the instream biota. Reduced base flows also impact on the marginal vegetation zone.

Ranked scenarios



Ranking rationale

Sc S1 and S32 do not meet the ecological objectives of the PES and REC and degrade the EcoStatus to a B/C from the current A/B EC. Scenario S31 is an improvement of these scenarios but the fish and riparian vegetation REC are not met. Scenario S6 maintains the REC and is ecologically the most acceptable scenario for EWR S3 and the KNP.

EWR S5 (MARITE RIVER)

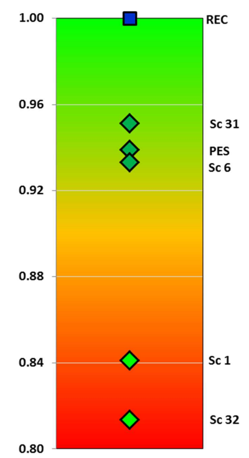
Ecological consequences as ECs

Component	PES	REC	Sc 1	Sc 31	Sc 32	Sc 6
Physico chemical	B	B	C	A/B	C	A/B
Geomorphology	C	C	C	C/D	C/D	C/D
Fish	B/C	B	C	B/C	C	B/C
Invertebrates	B/C	B	C	B	C	B/C
Riparian vegetation	B/C	B	B/C	B/C	B/C	B/C
EcoStatus	B/C	B	C	B/C	C	B/C

Ecological consequences

Geomorphological impacts (Sc S6, S31 and S32) are small and largely related to the dam and the changes in sediment regime. These changes, as well as the WQ changes, result in a decrease in the fish status under Sc S1, and S32 due to the unseasonal high flows released from Inyaka Dam. Sc S31 is however an improvement from Sc S6 as flows is generally lower. Scenario S32 flows are lower than the EWR requirement which results in increased stress.

Ranked scenarios



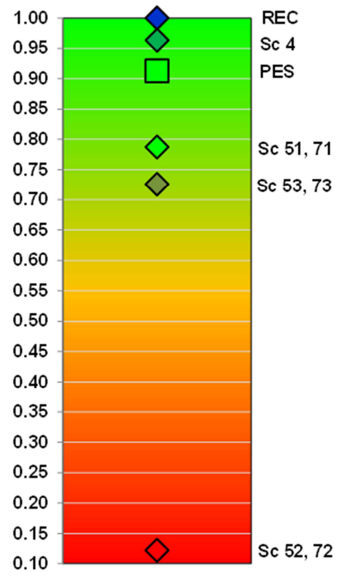
Ranking rationale

Inyaka Dam is situated in the Marite River upstream of EWR S5. Operation of the Sabie River is dependant on releases from Inyaka Dam, whether it is for the EWR and/or the users. As is currently the case, the impacts of this operating rule on the Marite River result in releases that do not mimic the natural seasonal distribution and often results in too much flows (i.e. flows higher than natural). None of the scenarios therefore achieve the REC. Scenario S31 is marginally better than the PES whereas Sc S1 and S32 result in in an EcoStatus below the PES.

EWR S6 (MUTLUMUVI RIVER)

Component	PES	REC	Sc 4	Sc 51, 71	Sc 52, 72	Sc 53, 73
Physico chemical	B/C	B/C	B/C	C	F	C
Geomorphology	C	C	C	D	F	D
Fish	C	B	B/C	C/D	F	D
Invertebrates	B/C	B	B	C	F	C/D
Riparian vegetation	C	B	B/C	C	F	C/D
EcoStatus	C	B	B/C	C	F	C/D

Scenario S52 and S72 are the worst case scenario as the river will barely ever flow and the EC of all components will decrease significantly. Low flows and floods also decrease under Sc S51, S53, S71 and S73 with the resulting degradation of most of the components linked to the geomorphological and WQ deterioration. Scenario S4 is the best option (as it does not include a dam) and improves the PES although not achieving the REC.

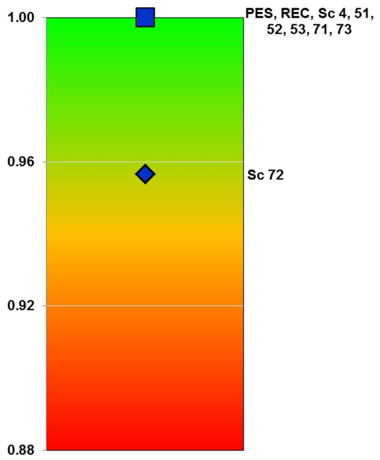


None of the scenarios meet the ecological objectives of the REC. Scenario S4 meets the ecological objectives of the PES and has the least impact of all the scenarios. Scenario S51 and S71 result in the PES EcoStatus although geomorphology and fish are impacted. Scenario S53 and S73 result in a deterioration in the PES while Sc S52 and S72 have serious impacts as the EWR site will receive zero flows except when the dam spills.

EWR S8 (SAND RIVER)

Component	PES	REC	Sc 4, 51, 52, 53, 71, 73	Sc 72
Physico chemical	B	B	B	B/C
Geomorphology	C	C	C	C
Fish	B	B	B	B
Invertebrates	B	B	B	B/C
Riparian vegetation	B	B	B	B
EcoStatus	B	B	B	B

The REC flows are met under all scenarios apart from Sc S72. Scenario S72 has marginally less base flows than the EWR resulting in invertebrates and WQ degrading by half a category.

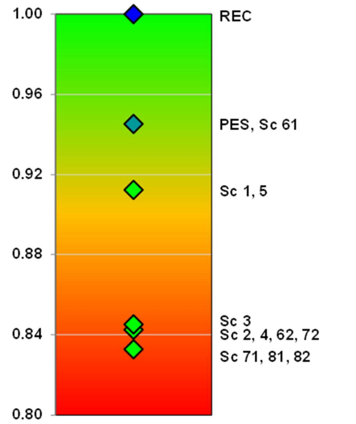


All the scenarios include return flows that are of such a scale that they ameliorate the impact of the proposed New Forest Dam and the reinstatement of forestry.

EWR C3 (CROCODILE RIVER)

Component	PES	REC	Sc 1	Sc 2, 3, 4, 62, 72	Sc 5	Sc 61	Sc 71, 81, 82
Physico chemical	C	B/C	B	B	B	B	B
Geomorphology	C	C	C/D	C/D	C/D	C/D	C/D
Fish	B	B	B	C	B	B	C/D
Invertebrates	C	B	C	C	C	C	C
Riparian vegetation	C	B	C	C	C	C	C
EcoStatus	B/C	B	C	C	C	B/C	C

Reduced flood peaks and reduced summer season baseflows all result in smaller, less frequent floods. This reduces scour of the bed, pools and lower banks and also promotes vegetation encroachment and channel width reduction (narrowing). These impacts and the increased high flows early in the dry season may result in flushing juvenile fish downstream.

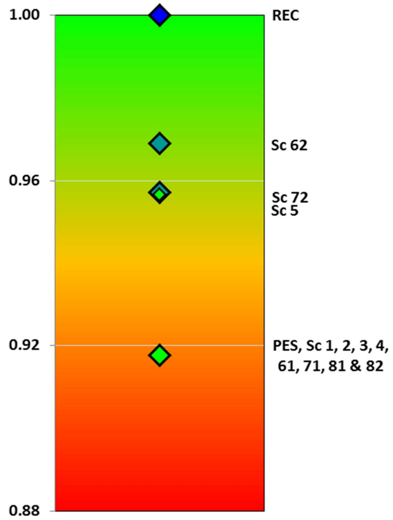


The results illustrate that none of the scenarios meet the ecological objectives of the REC. Only Sc C61 maintains the EcoStatus PES although there is deterioration in geomorphology. The major issue is that EWR C3 is downstream of Kwena Dam and that current and scenario releases are unseasonal resulting in too high flows in winter and too little flows in summer.

EWR C4 (CROCODILE RIVER)

Component	PES	REC	Sc 1,2.3,4, 61, 71, 81, 82	Sc 5	Sc 62, 72
Physico chemical	C	B	C	B	B
Geomorphology	B/C	B	B/C	B/C	B/C
Fish	B	B	B	A/B	A
Invertebrates	C	B	C	B	A/B
Riparian vegetation	C	B	C	C	C
EcoStatus	C	B	C	C	B/C

As there are no large dams which can inhibit the provision of flood flows this far down the catchment (the impact of altered spills from the upstream Kwena Dam will not have a measureable impact on geomorphology at this site due to amelioration from numerous tributary inputs), moderate and large floods necessary for channel maintenance will still occur. Instream biota remains in the PES or improves due to improved low flow conditions.

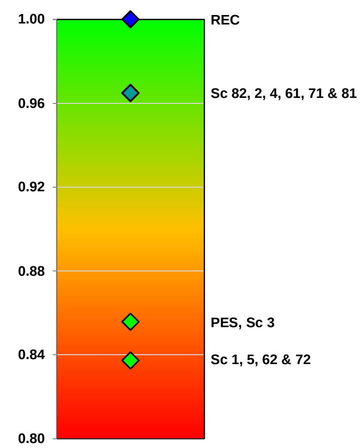


The results illustrate that all the scenarios meet the ecological objectives of the PES and of these scenarios; Sc C62 and C72 result in an improvement in the PES, although the REC requirements are not met. This site is upstream of the major off-takes into canals for irrigation further downstream and the problems (current and with scenarios) are the constraints on the operation for irrigation resulting in an unseasonal distribution of flows.

EWR C5 (CROCODILE RIVER)

Component	PES	REC	Sc 3	Sc 1, 5 62, 72	Sc 2, 4, 61, 71, 81, 82
Physico chemical	C	B	C	C	B/C
Geomorphology	C/D	C	C/D	C/D	C/D
Fish	C	B	C	C	B/C
Invertebrates	C	B	C	C	B
Riparian vegetation	C	B	C	C	B/C
EcoStatus	C	B	C	C	B/C

As there are no large dams which can supply floods this far down the catchment, the scenario will not have a measureable impact on geomorphology at this site due to amelioration from numerous tributary inputs. Instream biota remains in the PES or improves due to improved wet season volumes for downstream irrigation.

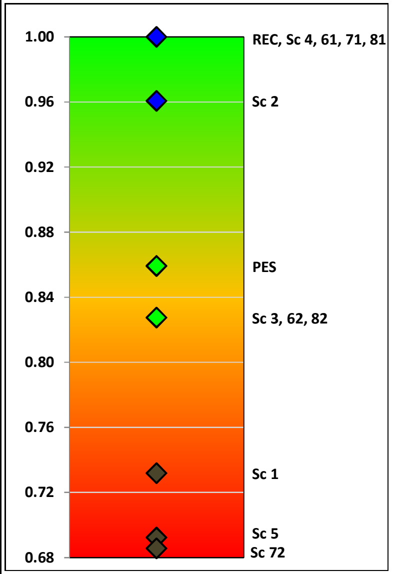


Most of the scenarios meet the ecological objectives of the PES and of these scenarios; ScC2, C4, C61, C71, C81 and C82 result in an improvement in the PES, although the REC requirements are not met. Scenario C1, C5, C62 and C72 result in the PES EcoStatus although low flows is lower than the PES requirement.

EWR C6 (CROCODILE RIVER)

Component	PES	REC	Sc 1	Sc 2	Sc 3, 62, 82	Sc 4	Sc 5	Sc 61, 71	Sc 72	Sc 81
Physico chemical	C	B	C	B	C	B	C/D	B	C/D	B
Geom	C	C	C	C	C	C	C/D	C	D	C
Fish	C	B	D	C	C/D	B	D	B	D	B
Invert	C	B	D	B/C	C	B	D	B	B	B
Riparian vegetation	C	B	B/C	B	B	B	C	B	C	B
EcoStatus	C	B	C	B	C	B	C/D	B	C/D	B

Scenario C5 and C72 impacts on the WQ and geomorphology due to reduced wet season flows below the PES. Fish will respond with possible impacts on fish functions such as spawning, breeding, nursery and migration. Although the situation is improved under Sc C62 and C82, the PES is still not achieved for all components although the EcoStatus is a C.

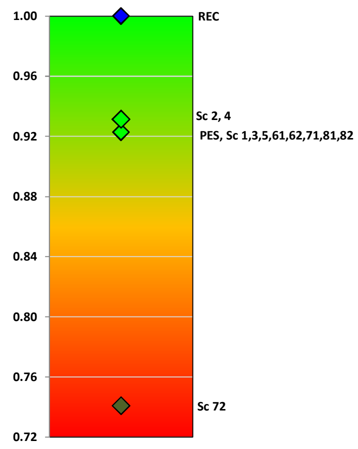


This site is the key site in the system, both from an operational and ecological importance viewpoint. The results illustrate that Sc C5 and Sc C72 do not meet the ecological objectives of the PES or the REC and are the worst case scenarios. ScenarioC4, C61, C71 and Sc C81 meet the REC requirements. ScenarioC2 also meets the REC requirements although the ecological objectives for invertebrates are not fully met. Scenario C1, C3, C62 and C82 meet the PES requirements however the instream biota are impacted to a greater extent under these scenarios and ecological objectives are not fully met for fish and macro-invertebrates.

EWR K7 (KAAP RIVER)

Component	PES	REC	Sc72,	Sc 2, 4	Sc 1,3,5, 61,62,71, 81,82
Physico chemical	B	B	C	B	B
Geomorphology	B	B	B	B	B
Fish	C	B	D	B	C
Invertebrates	B	B	C/D	B/C	B
Riparian vegetation	C/D	B/C	C/D	C/D	C/D
EcoStatus	C	B	C/D	C	C

The evaluation against EWR was made based on the assumption that the EWR should not be higher than PD flows during the dry season. All scenarios meet the PES or marginally improve the PES (Sc C2 and C4) except for Sc C72 results in a drop in most categories and results in a C/D EcoStatus. The reason for the lower EC is due to lower flows than the EWR and the PD during the dry months which impacts on the WQ and instream biota.

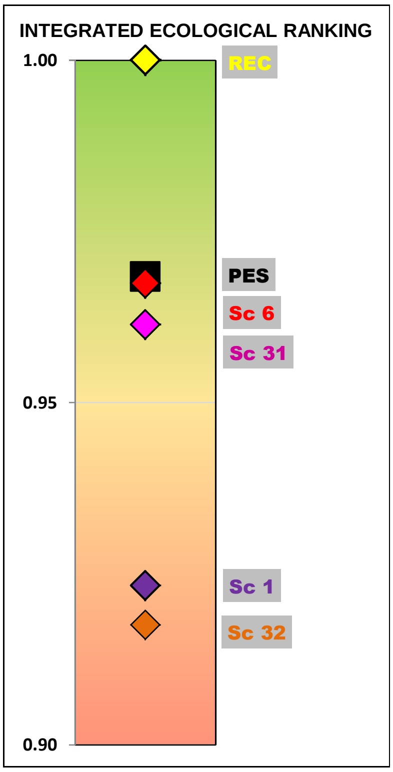


Scenario C72 does not meet the ecological objectives of the PES or the REC. The rest of the scenarios meet the PES EcoStatus requirements although and all component requirements. Of these scenarios, Sc C2 and C4 are the best scenarios as the fish improves a category.

Scenarios have minimal impact in the Komati system. The results at EWR K3 illustrate that all the scenarios meet the ecological objectives. Scenario K43 is the best scenario as it results in improved conditions for all the components except riparian vegetation which remains stable. The scenario evaluation on the Lomati River (EWR L3) indicate that Sc K2, K31 and K41 are similar to the PES whereas the other scenarios are in a worse state due to the impacts on riparian vegetation which in turn impacts the instream components. This results in a C/D EcoStatus.

INTEGRATED RANKING OF THE SCENARIOS ON THE SABIE RIVER SYSTEM

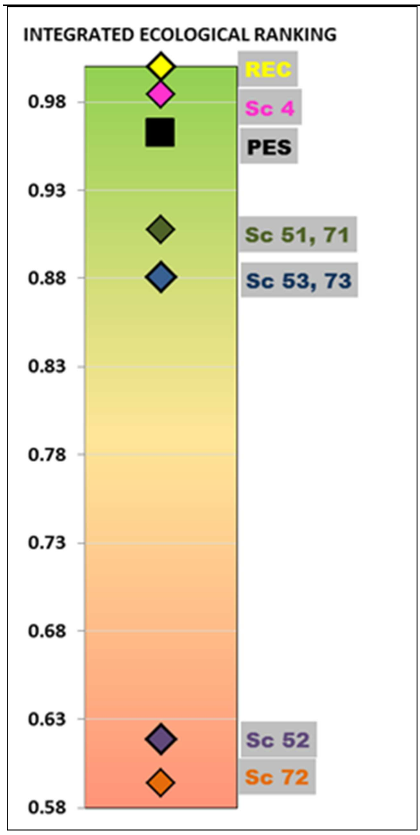
There are five sites on the Sabie system, of which two sites are impacted by scenarios. These need to be integrated based on a system of weighting the importance of the sites. The site weight indicates that EWR S3 carries the highest weight due to its high ecological importance and as it represents the KNP. The integrated ranking is shown in the figure below.



Scenario S31 and S6 are the best options as they are the closest to meeting the ecological objectives. If one however considers that the Sabie River has always been seen as the flagship river in the KNP as well as one of the few rivers left in South Africa in excellent condition, then the ranking order of the Sabie River should (from an ecological view point) override the integrated ranking. As Sc S6 is the only scenario that maintains the PES (and REC) in the Sabie River, this scenario is the ecological recommendation.

INTEGRATED RANKING OF THE SCENARIOS ON THE SAND RIVER SYSTEM

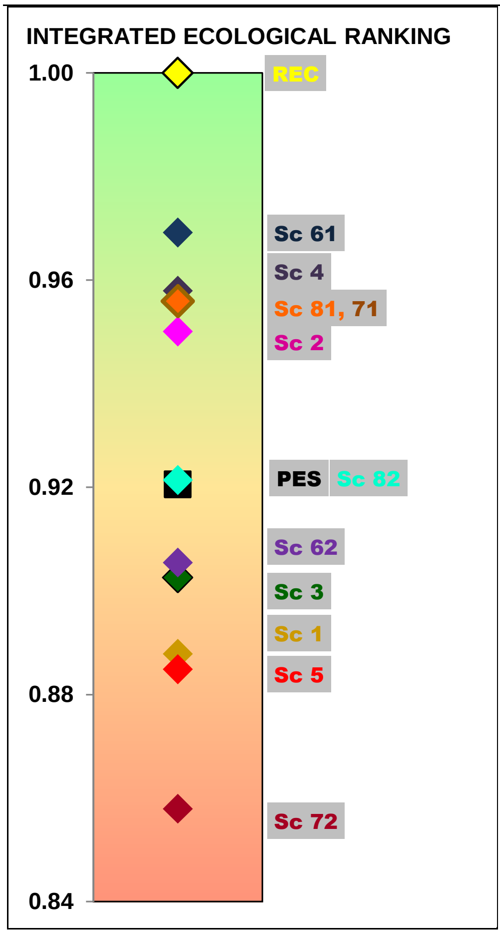
There are three sites on the Sand system, of which two sites were used for scenario evaluation. These need to be integrated based on a system of weighting the importance of the sites. The site weight indicates that EWR S8 carries the highest weight due to its high ecological importance and as it represents the KNP. The integrated ranking is shown in the figure below.



Scenario S52 and S72 are not viable options as a section of the Mutlumuvi River will change to a seasonal system. Scenario S4, although the best option, was recognised not to be a realistic option as the return flows associated with this scenario are too high. Scenario S51 and S53 also include these return flows. The remaining scenarios are Sc S71 and S73. Scenario S71 includes a full EWR release which will have a major impact on the yield. To further optimise, it is recommended that Sc S73 be further investigated.

INTEGRATED RANKING OF THE SCENARIOS ON THE CROCODILE RIVER SYSTEM

There are seven EWR sites on the Crocodile system, of which five EWR sites are impacted on by the scenarios. These need to be integrated based on a system of weighting the importance of the sites. The site weight indicates that EWR C6 carries the highest weight due to its high ecological importance and as it represents the KNP. Furthermore it is situated at the most downstream reach of the Crocodile River system and therefore plays an important role in monitoring. The integrated ranking is shown in the figure below.



The worst case scenarios are Sc C72 and C5 which both include new dam options but with no EWR releases. Scenario C1 which represents the current operating rule also has the potential to degrade the river although it will still maintain the EcoStatus of a C at EWR C6. The best options are those options that include the REC. It is however known that these have serious potential economic consequences. Scenario C3 (with no new dams) and Scenario C82 (that includes new dams) are potentially the best compromise options to explore further.

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ACRONYMS

CD: RDM	Chief Directorate: water Ecosystems
DARDLA	Department of Rural Development and Land Affairs
DS	Downstream
DWA	Department Water Affairs (Name change from DWAF applicable after April 2009)
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation (Name change from DWA applicable after May 2014)
EC	Ecological Category
EGSA	Ecosystem Goods, Services and Attributes
EWR	Ecological Water Requirement
FDI	Flow dependant cobble dwelling macroinvertebrates
FRAI	Fish Response Assessment Index
GAI	Geomorphology Assessment Index
IIMA	Interim IncoMaputo Agreement
IWAAS	Inkomati Water Availability Assessment Study
KNP	Kruger National Park
LSR	Large semi-rheophilic fish species
MAR	Mean Annual Runoff
MIRAI	Macroinvertebrate Response Assessment Index
PAI	Physico-chemical Driver Assessment Index
PD	Present Day
PSP	Professional Service Provider
REC	Recommended Ecological Category
RQOs	Resource Quality Objectives
Sc	Scenario
SR	Small rheophilic fish species
VEGRAI	Riparian Vegetation Response Assessment Index
WMA	Water Management Area

1 INTRODUCTION

1.1 BACKGROUND

The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) initiated a study during 2013 for the provision of professional services to undertake the determination of water resource classes and associated Resource Quality Objectives (RQOs) in the Inkomati Water Management Area (WMA). IWR Water Resources was appointed as the Professional Service Provider (PSP) to undertake this study which is managed by Rivers for Africa for IWR Water Resources.

1.2 STUDY AREA OVERVIEW

The study area comprises the Komati, Crocodile East and Sabie-Sand rivers, as shown in Figure 1.1. These three major tributaries of the international Incomati River Basin are operated largely independently of each other and are therefore described in this section as separate entities.

The Komati River rises in South Africa and flows into Swaziland, then re-enters South Africa where it is joined by the Crocodile River at the border with Mozambique, before flowing into Mozambique as the Incomati River. The Kruger National Park (KNP) is partially located in the Sabie and Crocodile catchments. The Crocodile River is located between the Komati and Sabie rivers. The Crocodile River joins the Komati River just before the border with Mozambique to form the Incomati River. The Sabie River catchment lies in the north of the Inkomati WMA, entering Mozambique after flowing through the Kruger National Park. Once in Mozambique, the Sabie joins the Komati River. The Sabie River catchment is considered the most pristine of the six river catchments that cross over from South Africa to Mozambique (DWA, 2013a).

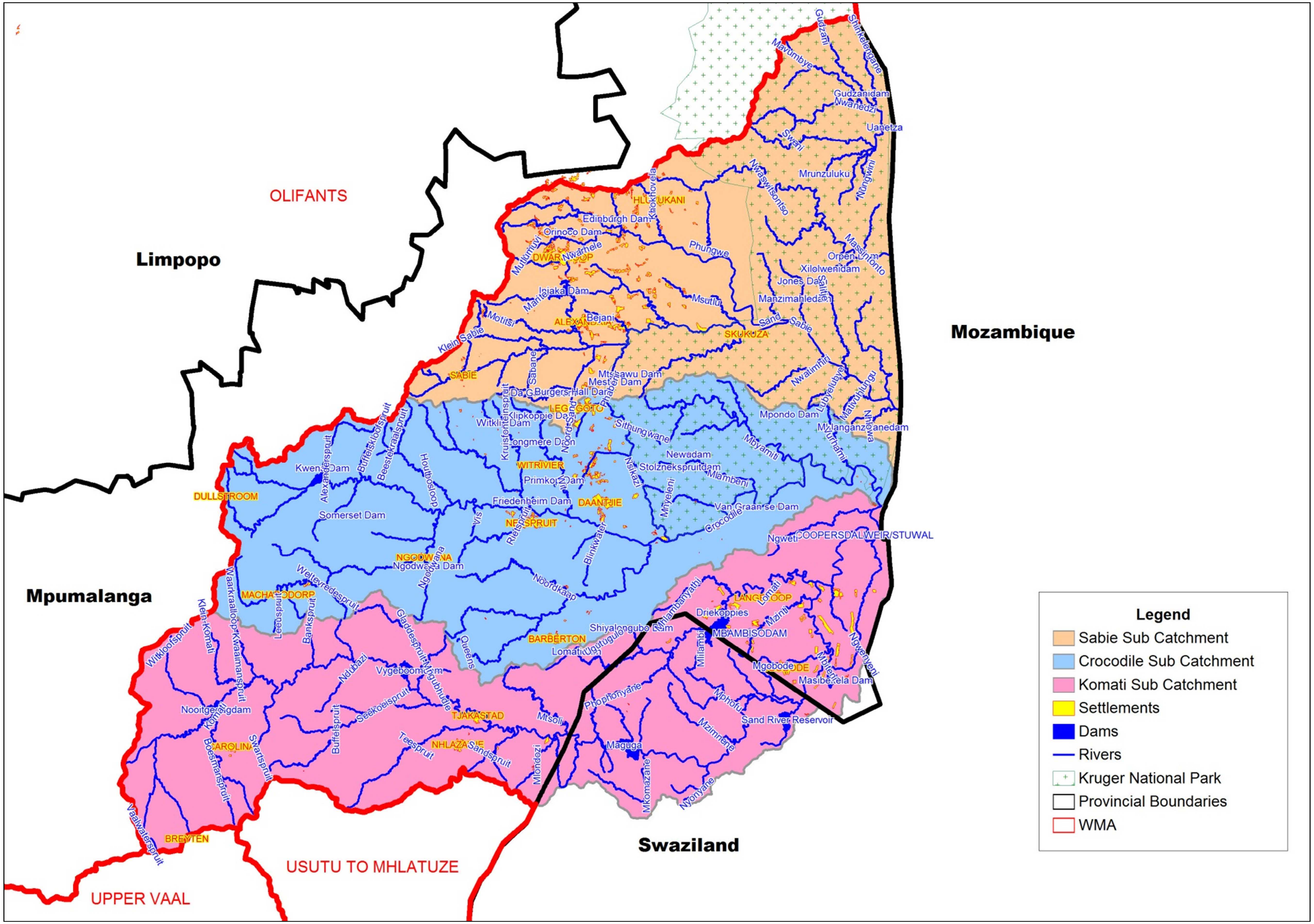

Figure 1.1 Study area – Inkomati WMA (DWA, 2013b)

1.3 INTEGRATED STEPS APPLIED IN THIS STUDY

The integrated steps for the National Water Classification System, the Reserve and RQOs are supplied in Table 1.1.

Table 1.1 Integrated study steps

Step	Description
1	Delineate the units of analysis and Resource Units, and describe the status quo of the water resource(s).
2	Initiation of stakeholder process and catchment visioning.
3	Quantify the Ecological Water Requirements and changes in non-water quality ecosystem goods, services and attributes.
4	**Identify and evaluate scenarios within the integrated water resource management process.**
5	Develop draft Water Resource Classes and test with stakeholders.
6	Develop draft RQOs and numerical limits.
7	Gazette and implement the class configuration and RQOs.

This report forms ***part*** of the outcomes of Step 4 (red above) within the integrated approach (DWA, 2013b). The objective of this task was to provide the scenario analysis, assumptions and results and document the consequences of the scenarios for the various components under Task D4 which are provided as two report volumes. The following steps will be presented in the two report volumes.

- River ecological consequences of the operational scenarios at the key biophysical nodes (Ecological Water Requirement (EWR) sites) by evaluating and determining the impact on the Ecological Category (EC).
- Economic consequences of operational scenarios by determining the impact of any water allocation changes.
- Assessment of the impacts of the various scenarios on Ecosystem Goods, Services and Attributes (EGSA) of operational scenarios to identify the direction of change (either positive or negative) and estimate the magnitude of the change in benefits and costs that may be experienced within the river system.
- Water quality consequences (other than water quality consequences associated with the ecological component)
- Integrate the consequences to provide preliminary Water Resource Class for stakeholder evaluation.

1.4 PURPOSE OF THE REPORT

The purpose of this report is to describe and document the river ecological consequences of the operational scenarios at the key biophysical nodes (EWR sites) by evaluating and determining the impact on the EC. This report provides supporting information to Report 4.1 where all the components addressed in Section 1.3 are summarised.

1.5 REPORT STRUCTURE

The report outline is provided below.

Chapter 1: Introduction

This Chapter provides general background to the project Task.

Chapter 2: Approach

This Chapter outlines the general approach to determining ecological consequences of operational scenarios

Chapter 3 – 13: Ecological Consequences

Detailed consequences of the operational scenarios on the various ecological components are provided for the Sabie, Sand, Crocodile and Komati River systems.

Chapter 14: Conclusions

The ecological consequences of the operational scenarios are summarised.

Chapter 15: References

Chapter 16: Appendix A: Stress indices

The stress indices are provided for the Sabie-Sand and Crocodile River systems.

Chapter 17: Appendix B: Report comments

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2 APPROACH: DETERMINING THE ECOLOGICAL CONSEQUENCES OF OPERATIONAL SCENARIOS

2.1 AVAILABLE DATA

All information used during the revision of the 2006 EcoClassification and Ecological Water Requirement (EWR) scenario determination (DWA, 2013; CSBS, 2014) was used as baseline for the Komati catchment assessment. The 2007 – 2010 Inkomati Reserve was finalised during 2010 (DWA, 2010a) and this data was used for the Crocodile, Sabie and Sand catchments, as the methods used are current and based on updated hydrology which was derived from the Inkomati Water Availability Assessment Study (IWAAS) completed by the DWS in 2009 (DWA, 2009a,b).

The suite of EcoStatus models used during this task was:

- Physico-chemical Driver Assessment Index (PAI): Kleynhans *et al*. (2005).
- Geomorphological Driver Assessment Index (GAI): Rountree and du Preez (in prep).
- Fish Response Assessment Index (FRAI): Kleynhans (2007).
- Macroinvertebrate Response Assessment Index (MIRAI): Thirion (2007).
- Riparian Vegetation Response Assessment Index (VEGRAI): Kleynhans *et al*. (2007).

The Present Ecological State (PES) results of the EWR sites situated in the Komati, Crocodile Sabie and Sand River system are provided below (Table 2.1 – 2.4). These results were updated were necessary and are documented in the EWR report (DWA, 2014).

Table 2.1 Komati River system: Summary of the PES levels for the components and the PES and REC for the EcoStatus (Level IV) results

Component	EWR K1	EWR K2	EWR K3	EWR G1	EWR T1	EWR L1
Physico chemical	B	B/C	D	C	C	B/C
Geomorphology	C	C	D/E	D	C	D
Fish	C	C	C/D	D	C	C
Macro-invertebrates	B/C	C	D	D	C	C
Riparian vegetation	C	C	D	D	C	B/C
EcoStatus (PES)	C	C	D	D	C	C
EcoStatus (REC)[1]	C	C	D	D	C	C

1 Recommended Ecological Category.

Table 2.2 Crocodile River system: Summary of the PES levels for the components and the PES and REC for the EcoStatus (Level IV) results

Component	EWR C1	EWR C2	EWR C3	EWR C4	EWR C5	EWR C6	EWR K7
Physico chemical	A	C	C	C	C	C	B
Geomorphology	B	B	C	B/C	C/D	C	B
Fish	A	B	B	B	C	C	C
Macro-invertebrates	B	B	C	C	C	C	B
Riparian vegetation	A	A/B	C	C	C	C	C/D

Component	EWR C1	EWR C2	EWR C3	EWR C4	EWR C5	EWR C6	EWR K7
EcoStatus (PES)	A/B	B	B/C	C	C	C	C
EcoStatus (REC)	A/B	B	B	B	B	B	B

Table 2.3 Sabie River system: Summary of the PES levels for the components and the PES and REC for the EcoStatus (Level IV) results

Component	EWR S1	EWR S2	EWR S3	EWR S4	EWR S5
Physico chemical	A	A/B	B	A/B	B
Geomorphology	B	B	B	A	C
Fish	B/C	B/C	B	B/C	B/C
Macro-invertebrates	B	B/C	B	A/B	B/C
Riparian vegetation	B/C	C	A/B	A/B	B/C
EcoStatus (PES)	B/C	C	A/B	B	B/C
EcoStatus (REC)*	B	B	A/B	A/B	B

* All improvements at EWR S1, S2 and S4 require non-flow related measures to be put in place. EWR S5 requires a change in seasonal distribution.

Table 2.4 Sand River system: Summary of the PES levels for the components and the PES and REC for the EcoStatus (Level IV) results

Component	EWR 6	EWR 7*	EWR 8
Physico chemical	B/C	C	B
Geomorphology	C	C/D	C
Fish	C	C	B
Macro-invertebrates	B/C	B/C	B
Riparian vegetation	C	C	B
EcoStatus (PES)	C	C	B
EcoStatus (REC)	B	B	B

* EWR S7 was not considered for ecological consequences due to the low confidence in the hydrology and the related interpretation of ecological responses. EWR S6 and S8 are therefore the key sites for further assessment.

2.2 PROCESS TO DETERMINE ECOLOGICAL CONSEQUENCES

The process is divided into chronological steps to determine the ecological consequences of the scenarios:

- The operational scenarios were modelled and a time series was provided for each scenario at each EWR site.
- The time series was converted to a flow duration table and both was provided to the physico-chemical and geomorphology specialist.
- These specialists had to provide the consequences and resulting EC of the operational scenario at the EWR sites.

Note: As only monthly modelling was available, the assessment of floods within scenarios will always be of lower confidence than the low or base flow assessment.

- The riparian vegetation specialist then assessed the response on the marginal and other riparian zones and supplied this information to the instream biota specialists. This was done prior to the instream biota assessment as riparian vegetation is a driver in terms of important habitat for the instream biota.
- Where required, the riparian vegetation specialist ran the VEGRAI model to predict the EC for the operational scenario.

This information formed the basis for the instream assessment to determine the responses to these driver changes for each scenario.

- Each time series was converted into a stress duration table and provided on a graph for two months (the same months evaluated during the EWR scenario determination) that included the EWR scenarios, natural, and present day (PD) hydrology.
- The operational scenarios were then compared to the EWRs set for various ECs. For example, if the operational scenario lies between the B EC and C EC for fish for a flow in the dry season, the operational scenario could either be a B, a B/C or a C.
- The information on the driver responses were also used to interpret the response to the operational scenarios.
- The VEGRAI, MIRAI and FRAI results (EC percentages and confidence evaluation) was used to determine the EcoStatus.

The approach to determine ecological consequences of the instream components are provided below.

1.1.1 Fish and Macro-invertebrates

The flow for each scenario (Sc) (Table 2.5) was presented as stress, based on the stress values calculated for the specific EWR site (see Table 2.6). The change in stress between the PES (EWR) and each scenario were then calculated (for each month and averaged per annum) (Table 2.7). The relative change was expressed as a change factor (based on the maximum stress category change of 10). This process was followed for the maintenance (70% flow duration) as well as the drought (95% flow duration) flows and the yearly average of this change factor was used as an indication of the expected change to the instream PES (FRAI or MIRAI). This change was then further refined based on the changes as indicated by the geomorphology, water quality and vegetation (marginal zone) specialists to determine the final estimated status (FRAI or MIRAI percentage) for each scenario. This approach ensured that the change under each scenario change be relative to the actual change in flows (and hence stress on biota).

Table 2.5 Maintenance (70% flow duration) flows (m^3/s) for different variables (including scenarios) for EWR S3 (Sabie River)

Month	Natural	Present Day	EWR PES	Sc S1	Sc S31	Sc S32
Oct	**4.457**	**2.572**	**2.572**	**0.692**	**1.904**	**0.745**
Nov	7.265	3.124	4.589	1.893	2.995	1.857
Dec	10.286	3.890	5.297	3.263	3.890	3.226
Jan	13.720	5.374	6.196	5.535	5.256	5.444
Feb	**16.777**	**8.043**	**10.932**	**8.930**	**8.149**	**8.115**
Mar	14.395	7.176	7.690	7.721	7.241	7.062
Apr	12.290	6.532	6.532	6.350	6.597	6.126
May	8.656	5.370	5.370	3.514	5.280	3.624

Month	Natural	Present Day	EWR PES	Sc S1	Sc S31	Sc S32
Jun	7.305	4.799	4.799	2.679	4.617	2.610
Jul	6.118	3.904	3.904	1.970	3.657	1.993
Aug	4.988	3.173	3.173	1.189	2.721	1.134
Sep	4.571	2.762	2.762	0.857	2.132	0.913

Table 2.6 Example of maintenance (70% flow duration) flows represented as stress (fish stress) at EWR S3 (Sabie River)

Month	Natural	PD	EWR PES	Sc 1	Sc 31	Sc 32
Oct	**5**	**6**	**6**	**10**	**7**	**10**
Nov	4	6	5	7	6	7
Dec	3	5	5	6	5	6
Jan	2	5	4	5	5	5
Feb	**0**	**3**	**2**	**3**	**3**	**3**
Mar	1	4	3	3	4	4
Apr	2	4	4	4	4	4
May	3	5	5	6	5	6
Jun	4	5	5	6	5	6
Jul	4	5	5	7	6	7
Aug	5	6	6	9	6	9
Sep	5	6	6	10	7	10

Table 2.7 Change in stress (fish) (70% maintenance flows) between PES (EWR) and the various scenarios assessed (negative values indicate increase in stress)

Month	Difference in stress (PES vs. Scenario)				Stress change factor		
	Sc S1	Sc S31	Sc S32		Sc S1	Sc S31	Sc S32
Oct	**-4.0**	**-1.0**	**-4.0**		**-40**	**-10**	**-40**
Nov	-2.0	-1.0	-2.0		**-20**	**-10**	**-20**
Dec	-1.0	0.0	-1.0		**-10**	**0**	**-10**
Jan	-1.0	-1.0	-1.0		**-10**	**-10**	**-10**
Feb	**-1.0**	**-1.0**	**-1.0**		**-10**	**-10**	**-10**
Mar	0.0	-1.0	-1.0		**0**	**-10**	**-10**
Apr	0.0	0.0	0.0		**0**	**0**	**0**
May	-1.0	0.0	-1.0		**-10**	**0**	**-10**
Jun	-1.0	0.0	-1.0		**-10**	**0**	**-10**
Jul	-2.0	-1.0	-2.0		**-20**	**-10**	**-20**
Aug	-3.0	0.0	-3.0		**-30**	**0**	**-30**
Sep	-4.0	-1.0	-4.0		**-40**	**-10**	**-40**
Average	**-1.7**	**-0.6**	**-1.8**		**-27**	**-7**	**-27**

2.3 PROCESS TO DETERMINE THE RANKING OF SCENARIOS PER EWR SITE

Once the change in ecological state was determined for each of the scenarios at a site, the scenarios had to be ranked from better to worse. Note that at this stage the ranking was ONLY considering the change in ecological state. The ranking illustrated the degree to which a scenario meets the REC (or one can describe it as the degree to which the ecological objectives which is represented by the REC are met). The scoring of one to zero is defined as follows:

- 1: REC is met for all components[1].
- 0: REC is not met at any component and each component would be evaluated individually as zero.

The concept per component and overall is the same. The following illustration is for one component, i.e. fish. Therefore, if the REC for fish is 62% and the scenario results in the fish being at 62%, then the resulting score would be a 1 (or 100% successful in meeting the REC for fish). If the resulting scenario results in fish being at 48%, then the score would be 0.77 (or 77% successful in meeting the fish REC).

Each component carries a standardised weight which is applied obtain an overall score for the scenario. Once all the scores for each scenario have been calculated, these can then be ranked and plotted on a traffic diagram illustrating the degree to which the EcoStatus is met.

2.4 EVALUATED SCENARIOS

The scenarios that were evaluated to assess ecological consequences at the various EWR sites are summarised in a matrix (Table 2.8 – 2.11). Detail regarding the scenarios and the yield modelling is supplied in Report 4.1.

For simplicity's sake, the scenarios below will be referred to by number and the letters will be left out.

Table 2.8 Summary of the Komati (X1) scenarios

Scenario	Scenario variables					
	Update water demands	Domestic growth and increase irrigation (plus restrictions so system does not fail)	IIMA[1] Flows	DARDLA[2]	Silingane Dam (DS[3] Maguga)	EWR
Sc K1	Yes	No	No	No	No	No
Sc K2	Yes	No	No	No	No	Yes
Sc K31	Yes	Yes	Yes	No	No	Yes
Sc K32	Yes	Yes	Yes	No	No	No
Sc K41	Yes	Yes	Yes	Yes	No	Yes
Sc K42	Yes	Yes	Yes	Yes	No	No
Sc K43	Yes	No	Yes	Yes	No	No
Sc K5	Water quality scenario (not for ecological assessment), includes mining aspects)					
Sc K6	Yes	Yes	Yes	Yes	Yes	Yes

1 Interim IncoMaputo Agreement. 2 Department of Rural Development and Land Affairs.
3 Downstream.

[1]Components: Drivers (physico-chemical, geomorphology) and responses (fish, macro-invertebrates, and riparian vegetation).

Table 2.9 Summary of the Crocodile (X2) scenarios

Scenario	Scenario Variables						
	Update water demands with revised PES EWR	Updated water demands	Domestic growth	IIMA Flows	Mountain View Dam (Kaap)	Boschjeskop Dam (Nels)	EWR
C1	Yes	No	No	No	No	No	No
C2	No	Yes	No	No	No	No	REC
C3	No	Yes	Yes	Yes	No	No	PES
C4	No	Yes	Yes	Yes	No	No	REC
C5	No	Yes	Yes	Yes	Yes	No	No
C61	No	Yes	Yes	Yes	Yes	No	REC
C62	No	Yes	Yes	Yes	Yes	No	PES
C71	No	Yes	Yes	Yes	No	Yes	REC
C72	No	Yes	Yes	Yes	No	Yes	No
C81	No	Yes	Yes	Yes	Yes	Yes	REC
C82	No	Yes	Yes	Yes	Yes	Yes	PES

Table 2.10 Summary of Sabie (X3) scenarios

Scenario	Update water demands	Growth in water demands	EWR
S1	Yes	No	No
S2	Yes	No	Yes (REC)
S31	Yes	Yes	Yes (REC)
S32	Yes	Yes	No
S6	Yes	Minimised to meet REC	Yes (REC)

Table 2.11 Summary of Sand (X3) scenarios

Scenario	Scenario variables				
	Update water demands	Growth in water demands	Reinstate Sand Forestry	New Forest Dam (Mutlumuvi River)	EWR
S4	Yes	Yes, with 50% return flows	No	No	No
S51	Yes	Yes, with 50% return flows	Yes (REC)	Yes	Yes REC
S52	Yes	Yes, with 50% return flows	Yes	Yes	No
S53	Yes	Yes, with 50% return flows	Yes (PES)	Yes	Yes PES
Sc71	Yes	Yes, with 25% return flows	Yes	Yes	Yes REC
Sc72	Yes	Yes, with 25% return flows	Yes	Yes	No
Sc73	Yes	Yes, with 25% return flows	Yes	Yes	Yes PES

2.5 EVALUATED EWR SITES

It is important to note that not all the EWR sites were evaluated. The EWR sites that were excluded from evaluation basically fall within two groups which are outlined below:

- **Group 1:** These EWR sites were unimpacted by the scenarios as the locality of the sites were outside the range of impacts. EWR sites which fell into this grouping were:
  - o Komati (X1) catchment: EWR G1 and EWR T1.
  - o Crocodile (X2) catchment: EWR C1 and EWR C2.

  - Sabie (X3) catchment: EWR S1, S2 and S4.
- **Group 2:** Although impacted by the scenario flows were similar to the REC or better and evaluation was therefore not required. EWR sites which fell into this grouping were:
  - Komati (X1) catchment: EWR K1 and EWR K2.

The following EWR sites were therefore evaluated:

- Komati (X1) catchment: EWR K3 and EWR L1.
- Crocodile (X2) catchment: EWR C3, C4, C5, C6, C7.
- Sabie (X3) catchment: EWR S3, S5.
- Sand (X3) catchment: EWR S6, S8.

In the case of EWR S7 in the Sand catchment, a decision was made to rather use EWR S8 lower down in the system to evaluate scenarios. This was based on the low confidence PD hydrology (due to lack of data) and the higher confidence at EWR S8. Furthermore, as this site is upstream of the Mutlumuvi confluence (EWR S6 is in the Mutlumuvi as well as the proposed New Forest Dam), the scenarios did not impact significantly on EWR S7.

3 SABIE-SAND RIVER SYSTEM (X3) - ECOLOGICAL CONSEQUENCES AT EWR S3 (KIDNEY): SABIE RIVER

Scenario (Sc) S1, S31 and S32 were evaluated at EWR S3. Scenario S2 represents PD with a full EWR release and was not evaluated. Under Sc S6 the REC requirements are provided and therefore this scenario was not assessed.

3.1 CHANGES IN FLOW REGIME

A summary of the effects of the operational scenarios is provided below:

- Sc S1: Relative to the PD (305 Mm^3) it represents a reduction in flow (303 Mm^3). Low flows are less than PD and the EWR requirement especially in the dry season.
- Sc S31: Relative to the PD (305 Mm^3) it represents a reduction in flow (292 Mm^3). Low flows are less than PD and the EWR requirement but mostly in dry season and less severe than Sc S1 and Sc S32.
- Sc S32: Relative to the PD (305 Mm^3) it represents a greater reduction in flow (276 Mm^3) than the other scenarios that were assessed. Low flows are less than PD and the EWR requirement especially in the dry season.
- Sc S6: Was developed after the first set of scenarios evaluation in an attempt to meet the EWR S3 requirements. This meant that growth in water demands has to be minimised to meet the EWR.

Although these volumes of annual flow are far in excess of the EWR requirement (at 184.6 Mm^3) necessary to achieve the REC, the reduced flows of some scenarios during key months would result in undesirable flow conditions for some ecosystem components at certain times of the year. Floods of all scenarios are similar to PD and meet the EWR requirement and permanence of flow in the channel.

The driver consequences are summarised in Table 3.1 and the response consequences in Table 3.2. Summaries are provided in Table 3.3 and Figure 3.1.

3.2 SABIE EWR S3: ECOLOGICAL DRIVER COMPONENTS

Table 3.1 Sabie EWR S3: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES and REC (B) (84.9%)		
1	C (75.2%)	An elevation in nutrients, turbidity and toxics will be seen, but the overriding contributor to the change in category is the expected increase in temperature levels and drop in oxygen with the significantly lower flows in the dry season.
31	B (85.5%)	Flows are similar to PD and the EC is expected to remain in a B.
32	C (75.2%)	An elevation in nutrients, turbidity and toxics will be seen, but the overriding contributor to the change in category is the expected increase in temperature levels and drop in oxygen with the significantly lower flows in the dry season.
Geomorphology: PES and REC (B) (84.6%)		
1	B (84.6%)	There is a less than 1% change in Mean Annual Runoff (MAR), and no perceptible difference in high flows and floods, between PD flow conditions versus those predicted under Sc S1. No change in habitat conditions is expected.
31	B (84.6%)	There is an approximately 4% reduction in MAR, and no perceptible difference in high flows and floods, between PD flow conditions versus those predicted under Sc S31. High flow/flood volumes are well in excess of those needed to meet the REC EWR

Sc	EC	Consequences
		requirement for geomorphology. No change in habitat conditions sufficient to result in a change in the EC for geomorphology is expected.
32	B (84.6%)	A more than 9% reduction in MAR is expected, but high flow/flood volumes are well in excess of those needed to meet the REC EWR requirement for geomorphology. No change in habitat conditions sufficient to result in a change in the EC for geomorphology is expected.

3.3 SABIE EWR S3: ECOLOGICAL RESPONSE COMPONENTS

The stress indices for fish and macro-invertebrates are provided in Appendix A and should be used in conjunction with the information provided for these components in Table 3.2.

Table 3.2 Sabie EWR S3: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES and REC (B) (85.6%)		
1	C 70.2%)	It is evident that there will be increased stress on fish under, both maintenance (70% flow duration) (average increase of 1.7 in stress) and drought (95% flow duration) (average increase of 1.4 in stress) flows. For maintenance flows, the dry season months (Jun - Nov) have a higher stress (2.7 increase in stress) compared to the wet season (only 0.7 increase in stress). The stress is especially high during Sep and Oct months (increase of 4 stress with fish now being exerted to a stress of 10). Under drought conditions (95% flow duration) the stress is also more notable in the dry season (average increase of 2 stress) than the wet season (0.8 stress) months. The increase in stress levels are the most significant in Nov, Oct and Jun. Overall the increased stress is therefore expected to result in a deterioration of the PES.
31	B/C (79.4%)	There will be only slightly increased stress on fish under both maintenance (70% flow duration) (average increase of 0.6 in stress) and drought (95% flow duration) (average increase of 0.7 in stress) flows. The increase in stress will be more significant in the dry season months than wet season months. The overall slight increase in stress level is estimated to result in a slight deterioration of the PES.
32	C (69.4%)	The flows and therefore related stress levels on fish will be very similar between Sc S1 and S32, in terms of both drought and maintenance flows as well as seasonal trends. It is therefore estimated that a similar trend of deterioration in PES can be expected (the only notable difference is slightly higher stress in the drought flows of the wet season month of Feb, which contribute to the overall slightly lower PES compared to Sc S1).
Macro-invertebrates: PES and REC (B) (86.9%)		
1	C (75.9%)	Decreased flows during the maintenance and drought periods, results in an increase in the stress. All the maintenance and drought months have high stress, between 1 and 3 and results in a deterioration of the PES.
31	B (82.6%)	A slight decrease in flows during the maintenance and drought periods results in an increase in the stress. Feb has a stress of 3 during the wet months and the PES will deteriorate.
32	C (75.5%)	Similar to Sc S1 and a decrease in flows during the maintenance and drought periods results in increased stress for all the maintenance and drought months (between 1 and 3) resulting in a deterioration of the PES.
Riparian vegetation: PES and REC (A/B) (89.3%)		
Vegetation response will be limited to marginal and lower zone because altered flows are mainly low flows. Upper zone and bank vegetation are unlikely to respond. Non-woody marginal zone vegetation cover was between 40 - 60% at time of assessment (Sep 2007). All scenarios result in slightly less inundation of marginal zone vegetation in the wet season, but reduction is small and likely less than 5 - 10%. Inundation of vegetation in the dry season is low for PD, the EWR requirement and Sc 31 and slightly reduced for Sc S1 and S32, and a likely reduction of 5 - 10% of what would have been inundated.		
1 32	B (85.7%)	Reduced base flows in dry season result in water stress of non-woody vegetation and a likely reduction in cover and abundance in the marginal and lower zones. This response is mitigated in the wet season due to the high flows that occur in addition to base flows.
31	B	Similar to Sc S1 but less severe.

Sc	EC	Consequences
	(87.3%)	

3.4 SABIE EWR S3: ECOSTATUS

The resulting ECs for each component and EcoStatus is provided in Table 3.3. The ranking of the scenarios are provided on a traffic diagram (Figure 3.1). The results illustrate that none of the scenarios meet the ecological objectives except for Sc S6 which supplies the EWR as a priority. After Sc S6, Sc S31 has the least impact as the deterioration in low flows during drought season is less severe than Sc 1 and 32.

Table 3.3 Ecological consequences at SABIE EWR S3

Component	PES& REC	Sc S1	Sc S31	Sc S32	Sc S6
Physico chemical	B	C	B	C	B
Geomorphology	B	B	B	B	B
Fish	B	C	B/C	C	B
Invertebrates	B	C	B	C	B
Riparian vegetation	A/B	B	B	B	A/B
EcoStatus	A/B	B/C	B	B/C	A/B

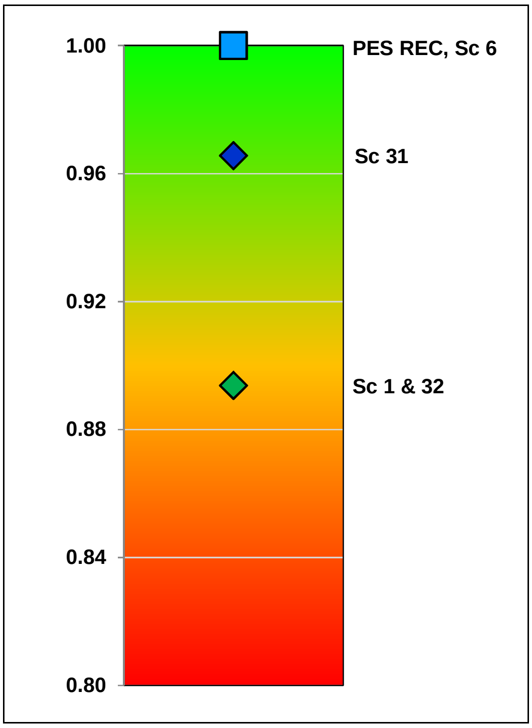

Figure 3.1 Ecological ranking of operational scenarios at SABIE EWR S3

4 SABIE-SAND RIVER SYSTEM (X3) - ECOLOGICAL CONSEQUENCES AT EWR S5 (KIDNEY): MARITE RIVER

Scenario S1, S31, and S32 were evaluated at EWR S5. Scenario S2 represents PD with a full EWR release and was not evaluated. Scenario S6 is similar to PD and was not further evaluated in detail, however specialists did check if the PES was maintained.

4.1 CHANGES IN FLOW REGIME

A summary of the effects of the operational scenarios is provided below:

- Sc S1: Relative to the PD (103 Mm^3) it represents a small reduction in flow (101 Mm^3). Scenario S1 and S32 are similar to each other with low flows less than the EWR PES and REC requirement.
- Sc S31: Relative to the PD (103 Mm^3) it represents a larger reduction in flow (90 Mm^3). Low flows under Sc S31 are less than PD and the EWR requirement in the wet season but mostly higher than PES and REC requirement in dry season.
- Sc S32: Relative to the PD (103 Mm^3) it represents a larger reduction in flow (78 Mm^3).

Although these volumes of annual flow are far in excess of the EWR requirement (at 45 Mm^3) necessary to achieve the REC, the reduced flows of some scenarios would result in undesirable flow conditions for some ecosystem components at certain times of the year. Floods of all scenarios are similar to PD (Sc S1 higher than PD at times) and much higher than the EWR requirement. All scenarios maintain permanence of flow in the channel with no increase (or occurrence) of zero flows.

The driver components are summarised in Table 4.1 and the response components in Table 4.2. Summaries are provided in Table 4.4 and Figure 4.1.

4.2 MARITE EWR S5: ECOLOGICAL DRIVER COMPONENTS

Table 4.1 Marite EWR S5: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES and REC (B) (84.4%)		
1	C (76.4%)	Although a similar impact on low flows is seen as for Sc S32, floods remain similar to present state so flushing flows are still present in the system. Although a deterioration in water quality is expected, it is not as severe as under Sc S32.
31	A/B (89.6%)	Low flow conditions are better under Sc S31 compared to Sc S1 and S32, and often exceed EWR requirements, but there is a small reduction in high (flushing) flows. A slight improvement in nutrients, temperature and oxygen conditions are expected.
32	C (65.8%)	The drop in low flows and reduction in flushing flows will result in a deterioration in water quality, particularly due to an increase in salt, nutrients, toxics and sediments. Concomitant changes in temperature and oxygen will also be seen.
Geomorphology: PES and REC (C) (65.2%)		
1	C (65.2%)	There will be more than sufficient volumes to meet the EWR requirements and there should be no decrease in the PES.
31	C/D (61.8%)	Although there will be sufficient volume to meet the EWR requirements at the MAR level, this scenario will provide flows that are less than the REC EWR wet season (Feb) baseflows and small flood requirements. These reduced flows are likely to cause a decrease in the instream habitat conditions due to reduced flushing and transport of sediments. A small deterioration in the PES is expected due to reduced flushing potential.
32	C/D	Although there will be sufficient volume to meet the EWR requirements at the MAR level,

Sc	EC	Consequences
	(57.9%)	this scenario will provide flows that are less than the REC EWR wet season (Feb) baseflows and small flood requirements. These reduced flows are likely to cause a decrease in the instream habitat conditions due to reduced flushing and transport of sediments. A reduction in the PES to a C/D is expected due to reduced flushing potential.

4.3 MARITE EWR S5: ECOLOGICAL RESPONSE COMPONENTS

The stress indices for fish and macro-invertebrates are provided in Appendix A and should be used in conjunction with the information provided for these components in Table 4.2.

Table 4.2 Marite EWR S5: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES (B/C) (77.9%) and REC (B) (84.4%)		
1	C (62.2%)	When comparing this scenario to the PES EWR flows, it is evident that there will be increased stress on fish under both, maintenance (70%) (average increase of 1.6 in stress) and drought flows (95%) (average increase of 1.6 in stress). For maintenance flows, the dry season months (Jun - Nov) have a higher (2.3 increase in stress) compared to the wet season (only 0.8 increase in stress). The stress is high during all dry season months but especially Sep and Oct (increase of 3 stress with fish now being exerted to a stress of 10). Under drought conditions (95% flow duration) the stress is similar between the wet and dry season and all months experience increase in stress with especially Feb being the most critical (increase in 3 stress). Overall deterioration will be more prominent in the dry season, although the wet season will also deteriorate resulting in an overall decrease of the PES to C.
31	B/C (81.3%)	When comparing this scenario with the PES EWR flows, it is evident that there will be an overall improvement in flows resulting in a decrease in stress in both the dry season and wet season. The improvement is more evident in the dry season where stress can be expected to be reduced by at least one stress category. The maintenance flows in the wet season will results in a slight increase in stress but due to the evident improvement in the dry season overall conditions for fish should improve. This improvement is slightly limited by altered wet season baseflows and floods. The overall decrease in stress level is however estimated to result in an improvement of the PES to an EC of B and may therefore meet the REC.
32	C (65%)	The flows and therefore related stress levels on fish will be very similar but slightly less under Sc 32 when compared to Sc S1. Increased stress is evident in both drought and maintenance flows as well as wet and dry months. The level of stress under maintenance flows will be similar between the wet and dry seasons but during droughts it is more profound in the dry season. Geomorphological changes due to decreased wet season baseflows and small floods may further increase the stress on fish in the wet season due to loss of habitat quality (reduced flushing, sedimentation). It is therefore estimated that a similar trend (compared to Sc S1) of a decrease in PES can be expected albeit slightly lower, resulting in a C EC.
Macro-invertebrates: PES (B/C) (80.5%) and REC (B) (86.3%)		
1	C (68.3%)	Compared with the PES, there is little impact on geomorphology, floods, water quality and vegetation parameters, but decreased flows during the maintenance and drought periods, result in an increase in the stress. Most of the maintenance and drought months have moderate stress (between 1 and 2) and the PES will deteriorate to a C.
31	B (83.2%)	Compared with the PES, there is little impact on the floods, water quality and vegetation parameters. The slight change in the geomorphology will increase stress, however an improvement in flows during the maintenance and drought periods, will result in a decrease in stress. Most of the drought months result in lower stress (between 1 and 2) resulting in an improvement in the PES.
32	C (68.8%)	Compared with the PES, there is little impact on the floods, water quality and vegetation parameters. The slight change in the geomorphology, and decreased flows during the maintenance and drought periods, result in an increase in stress. Some of the maintenance and drought months have moderate stress (between 1 and 2) and the PES will deteriorate.
Riparian vegetation: PES (B/C) (80.4%) and REC (B) (84.5%)		

Sc	EC	Consequences
The altered flows mainly pertain to low flows and therefore the vegetation response will be limited to marginal and lower zones. Upper zone and bank vegetation are unlikely to respond. Non-woody marginal zone vegetation cover was between 40 - 60% at time of assessment (Sep 2007). All scenarios result in slightly less inundation of the marginal zone vegetation in the wet season, but the reduction is small and likely less than 5 - 10%. Inundation of vegetation in the dry season is low for PD, the EWR requirement and Sc S31 and slightly reduced for Sc S1 and S32, and a likely reduction of 5 - 10% of what would have been inundated will occur.		
1 32	B/C (81.9%)	Higher high flows in the summer are likely to reduce some of the alien invasion, so slight improvement in PES is expected.
31	B/C (80.4%)	No change in the PES is expected.

4.4 MARITE EWR S5: ECOSTATUS

Geomorphological impacts (Sc S6, S31 and S32) are small and largely related to the dam and the changes in sediment regime. These changes, as well as the WQ changes, result in a decrease in the fish status under Sc S1, and S32 due to the unseasonal high flows released from Inyaka Dam. Sc S31 is however an improvement from Sc S6 as flows is generally lower. Scenario S32 flows are lower than the EWR requirement which results in increased stress.

Table 4.3 Ecological consequences at MARITE EWR S5

Component	PES	REC	Sc S1	Sc S31	Sc S32	Sc S6
Physico chemical	B	B	C	A/B	C	A/B
Geomorphology	C	C	C	C/D	C/D	C/D
Fish	B/C	B	C	B/C	C	B/C
Invertebrates	B/C	B	C	B	C	B/C
Riparian vegetation	B/C	B	B/C	B/C	B/C	B/C
EcoStatus	B/C	B	C	B/C	C	B/C

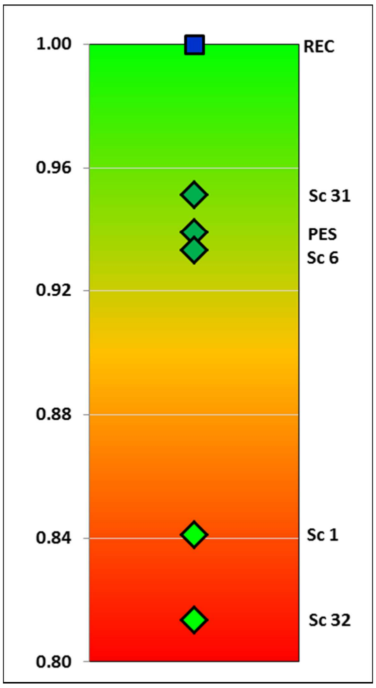

Figure 4.1 Ecological ranking of operational scenarios at MARITE EWR S5

5 SABIE-SAND RIVER SYSTEM (X3) - ECOLOGICAL CONSEQUENCES AT EWR S6 (MUTLUMUVI): MUTLUMUVI RIVER

Scenario S4, S51, S53, S71, S72 and S73 were evaluated at EWR S6. Various scenarios were not assessed and the reasoning is summarised below:

- Scenario S2 was not evaluated as it represents PD with a full EWR release, i.e. the consequences are known.
- Values for Sc S52 and S72 were derived. The EWR site is situated immediately downstream of the dam which results in a major impact as no flows apart dam spills part these site. The conclusions are therefore obvious that it would change to an F river.
- Scenario S51 is the same as S71, S52 the same as S72 and S53 the same as S73.

5.1 CHANGES IN FLOW REGIME

A summary of the effects of the operational scenarios is provided below:

- Sc S4: relative the PD (37 Mm^3) represents an increase in flows (47 Mm^3), which is more than the natural MAR (45 Mm^3) despite incorporating an increase in water demands and afforestation of the upper catchment. This increase (above natural) is due to return flows from towns in the catchment that are to be supplied by an interbasin transfer from Inyaka Dam in the adjacent Sabie catchment.

Scenarios S51 and S53 represent scenarios incorporating a new dam (the New Forest Dam):

- Sc S51: Relative the PD (37 Mm^3) it represents a reduction in flow (27.8 Mm^3) that is still in excess of the annual 18 Mm^3 EWR requirements and provides the low flow EWRs for the REC.
- Sc S53: Relative the PD (37 Mm^3) it represents a reduction in flow (25.6 Mm^3) that is still in excess of the annual 18 Mm^3 EWR requirements and provides the low flow EWRs for the PES.
- Sc S52: The river changes from a perennial system to an ephemeral system which only receives water when the dam spills.

Although these volumes of annual flow are far in excess of the EWR requirement (at 45 Mm^3) necessary to achieve the REC, the reduced flows of some scenarios would result in undesirable flow conditions for some ecosystem components at certain times of the year. Floods of all scenarios are similar to PD and much higher than the EWR requirement. All scenarios maintain permanence of flow in the channel with no increase (or occurrence) of zero flows.

The driver components are summarised in Table 5.1 and the response components in Table 5.2. Summaries are provided in Table 5.4 and Figure 5.1.

5.2 MUTLUMUVI EWR S6: ECOLOGICAL DRIVER COMPONENTS

Table 5.1 Mutlumuvi EWR S6: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES and REC (B/C) (80.9%)		
4	B/C (77.6%)	Higher flows in the dry season (often more than natural) due to increased return flows could result in an improved water quality state in the river due to a dilution of salts, nutrients and toxics, assuming treatment to an appropriate standard. The alternative would be an additional nutrient and toxics load from return flows. Due to the uncertainties, a small increase in salts, nutrients and toxics is assumed due to higher return flows, although the impact is dampened by higher water volumes.
51	C	New Forest Dam upstream, which spills very seldom, will result in reduced baseflows

Sc	EC	Consequences
71	(74.8%)	during the wet season and unchanged dry season baseflows and floods. Water quality is therefore expected to be stable under those conditions, although salts, nutrients and toxics may increase due to the increased return flows. Dam-related impacts on temperature and oxygen are also expected.
53 73	C (70.4%)	The pattern is similar to that of Sc S51, although flows in the dry season are lower than the PES and REC, with an impact on nutrient and temperatures. A further impact on nutrients, salts and toxics is expected due to increased return flows. Dam-related impacts on temperature and oxygen are also anticipated.
Geomorphology: PES and REC (C) (71%)		
4	C (71%)	These scenarios are indistinguishable from the PD flows and there will be no change in the PES of the geomorphology.
51 71	D (50%)	A new dam on the Mutlumuvi River will result in fewer floods reaching the EWR site. This dam will cause a reduction in the provision of floods to the site and will not meet the wet season EWR requirements for floods, as only low flow EWRs would be released by the dam and the spills analysis (indicating the provision of floods) show that there would be periods of up to 10 years at a time with no flood provision. Additionally, the upstream dam would cut off sediment. In-channel habitat would degrade slightly as a result of reduced floods and cutting off of sediment supply.
53 73	D (48%)	The reduction in the provision of floods to the site is more severe under Sc S53 than Sc S51 resulting in similar impacts although greater in extent.

5.3 MUTLUMUVI EWR S6: ECOLOGICAL RESPONSE COMPONENTS

The stress indices for fish and macro-invertebrates are provided in Appendix A and should be used in conjunction with the information provided for these components in Table 5.2.

Table 5.2 Mutlumuvi EWR S6: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES (C) (69.2%) and REC (B) (83%)		
4	B/C (81.9%)	When comparing this scenario with the PES EWR flows, it is evident that there will be less stress on fish, under both maintenance (70%) and drought (95%) flows. The decreased stress (increased flows) will be notable for both the wet and dry season, being more significant for the wet season. A notable improvement in the marginal vegetation will also occur and will improve conditions for fish with a preference for this habitat feature, resulting in further improvement in the ecological status. The only deteriorating factor expected is water quality deterioration due to the quality of the return flows potentially being jeopardised. The non-flow related water quality deterioration was therefore considered and the ecological status of the fish was decreased. Conditions are therefore estimated to improve to an EC of B/C.
51 71	C/D (60.2%)	Base flows will generally be better compared to the PES (EWR) flows (except for month of Feb). In terms of base flow the condition of fish is therefore estimated to remain very similar, but changes are expected due to especially flood alteration and water quality deterioration. The impact of return flows and reduced flushing will further decrease the water quality, while geomorphological and marginal vegetation impacts will now be more evident. The impact of the new dam on the migratory success of potamodromous and catadromous species is furthermore expected to reduce the integrity of fish. Overall the ecological status of the fish is therefore estimated to decrease to a C/D.
53 73	D (55%)	As observed at Sc S51, the base flow impacts will be minimal and should not result in significant alterations in the integrity of the fish assemblage. The exception is for the wet season flows in Feb where an increase of 5 stress is estimated under maintenance flows. This coupled with the increased stress due to flood reduction (geomorphology and marginal vegetation) and a further decrease in water quality (return flows and flood reduction) is estimated to cause a more noted decrease in the overall condition of the fish assemblage to an EC of D.
Macro-invertebrates: PES (B/C) (77.7%) and REC (B) (87.1%)		
4	B (83.2%)	Compared with the PES, there is little impact on the geomorphology and floods. Water quality deteriorated somewhat and vegetation parameters improved marginally. Most of the flows improved during the maintenance and drought periods, resulting in decreased

Sc	EC	Consequences
		stress. Most of the months have lower stress values (between 1 and 3) and an improvement in the PES is expected.
51 71	C (68.8%)	Due to the proposed dam, changes are expected and include less floods, altered geomorphology, deterioration in water quality and vegetation parameters, as well as reduced flows during the maintenance periods, resulting in an increase in stress. The PES is expected to deteriorate.
53 73	C/D (61.2%)	Floods are limited to spills resulting in altered geomorphology, deterioration in water quality and vegetation parameters. Low flow requirements for the PES are met in the dry season but not in the wet season. February has stress of 6 resulting in a deterioration in the PES.
Riparian vegetation: PES (C) (75.6%) and REC (B) (84.7%)		
4	B/C (78.0%)	Increased inundation of marginal zone vegetation in the dry and wet season, but inundation stress is negligible and will favour vegetation abundance and vigour. Expect non-woody cover to increase in marginal and lower zones.
51 71	C (65.6%)	Low flow requirements for the REC are met in the dry season but not in the wet season. Floods are limited to spills from the new dam. Reduced wet season base flows result in less inundation of marginal and lower zone vegetation with some populations (*Cyperus dives*) experiencing a lack of inundation in the wet season. This will likely result in some reduced reproductive output and increased water stress, and may affect recruitment in the long term. Density of riparian obligates likely to decrease while terrestrial species in the riparian zone will benefit.
53 73	C/D (60.8%)	Low flow requirements for PES are met in the dry season but not in the wet season. Floods are limited to spills from the new dam. Reduced wet season base flows result in less inundation of marginal and lower zone vegetation with some populations (*C. dives* and *Breonadia salicina*) experiencing a lack of inundation in the wet season. This will likely result in some reduced reproductive output and increased water stress, and may affect recruitment in the long term. Density of riparian obligates are likely to decrease while terrestrial species in the riparian zone will benefit.

5.4 MUTLUMUVI EWR S6: ECOSTATUS

The resulting ECs for each component and EcoStatus is provided in Table 5.3. The ranking of the scenarios are provided on a traffic diagram (Figure 5.1). The results illustrate that none of the scenarios meet the ecological objectives of the REC. Scenario 4 meets the ecological objectives of the PES and has the least impact of all the scenarios. Scenario S51 and S71 result in the PES EcoStatus although geomorphology and fish are impacted. Scenario S53 and S73 result in a deterioration in the PES while Sc S52 and S72 as the EWR site will receive zero flows except when the dam spills.

Table 5.3 Ecological consequences at MUTLUMUVI EWR S6

Component	PES	REC	Sc S4	Sc S51, S71	Sc S52, S72	Sc S53, S73
Physico chemical	B/C	B/C	B/C	C	F	C
Geomorphology	C	C	C	D	F	D
Fish	C	B	B/C	C/D	F	D
Invertebrates	B/C	B	B	C	F	C/D
Riparian vegetation	C	B	B/C	C	F	C/D
EcoStatus	C	B	B/C	C	F	C/D

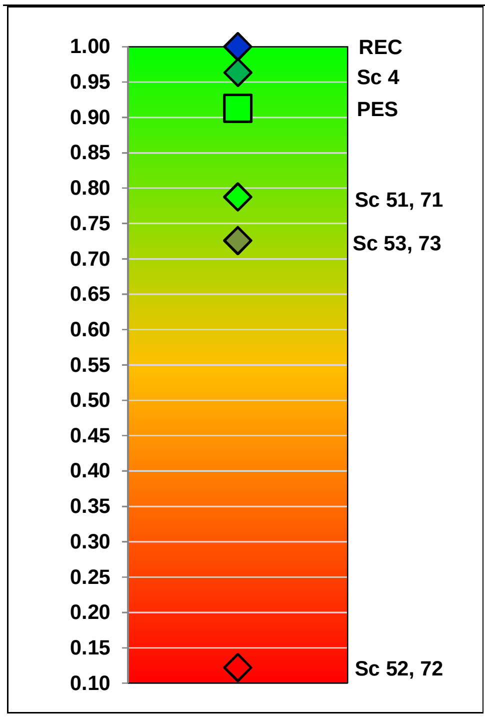

Figure 5.1 Ecological ranking of operational scenarios at MUTLUMUVIEWR S6

6 SABIE-SAND RIVER SYSTEM (X3) - ECOLOGICAL CONSEQUENCES AT EWR S8 (SAND): SAND RIVER

Scenario S4, S51, S52, S53, S71 S72 and S73 are relevant at Sand EWR S8. Relative to the PD MAR (104 Mm^3); the scenarios all exceed the EWR requirements of 30 Mm^3. The flow patterns of the scenarios are indistinguishable or better than the PD flow conditions, and thus PES is not expected to decline under these flow scenarios. It was thus not necessary to evaluate the ecological consequences of these scenarios at this site. Although affected by the proposed dam under Sc S51, 52 and 53, the impacts of these scenarios are ameliorated by the return flows from the lower catchment. Scenario S72 is marginally lower than the EWR during some months but does maintain the REC for all components and the EcoStatus.

Summaries are provided in Table 6.1 and Figure 6.1.

Table 6.1 Ecological consequences at SAND EWR S8

Component	PES	REC	Sc S4	Sc S51	Sc S53	Sc S71	Sc S72	Sc S73
Physico chemical	B	B	B	B	B	B	B/C	B
Geomorphology	C	C	C	C	C	C	C	C
Fish	B	B	B	B	B	B	B	B
Invertebrates	B	B	B	B	B	B	B/C	B
Riparian vegetation	B	B	B	B	B	B	B	B
EcoStatus	B	B	B	B	B	B	B	B

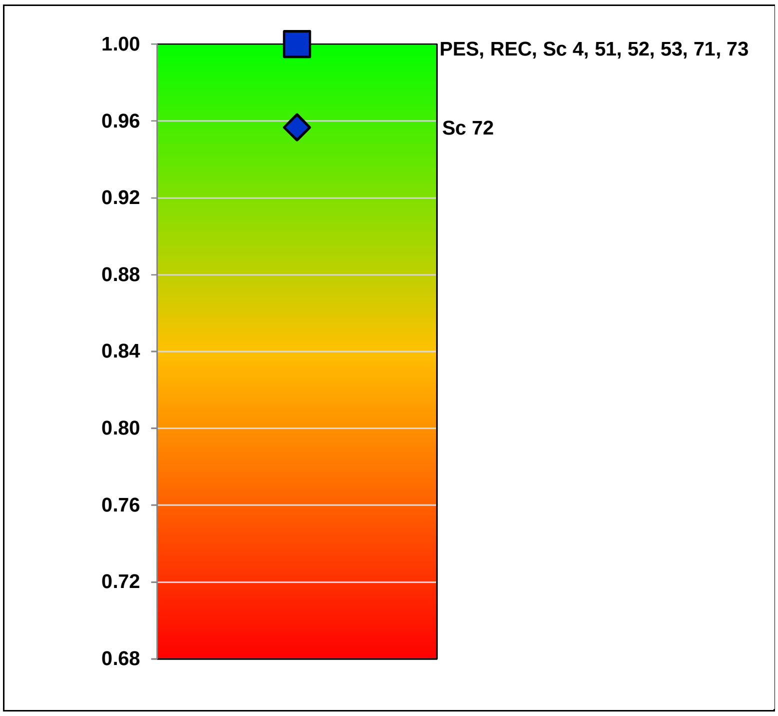

Figure 6.1 Ecological ranking of operational scenarios at TLULANDZITEKA EWR S8

7 CROCODILE RIVER SYSTEM (X2) - ECOLOGICAL CONSEQUENCES AT EWR C3 (POPLAR CREEK): CROCODILE RIVER

Scenario C1, C2, C3, C61 and Sc C71 was evaluated at EWR C3. The analysis of the operational scenarios indicated that the following scenarios were similar:

- Sc C1 was similar to Sc C5.
- Sc C2 was similar to Sc C4, Sc C62 and Sc C72.
- Sc C71 was similar to Sc C81 and Sc C82.

Therefore Sc C1, C2 and Sc C71 represent these scenarios respectively and were evaluated.

7.1 CHANGES IN FLOW REGIME

At EWR C3, the PD MAR is 159 Mm^3 and volume necessary to achieve the PES is 95 Mm^3. A summary of the effects of the operational scenarios is provided below:

- Sc C1: Relative to the PD (159 Mm^3) this scenario provides similar flows (159 Mm^3).
- Sc C2: Relative to the PD (159 Mm^3) the PES/REC flow requirements are exceeded (162 Mm^3). Stream permanency is 100%. Under this scenario natural flows are often exceeded especially in the dry season. Seasonality is similar to PD, but different from natural and both PES (95 Mm^3) and REC requirements. Dry season flows are generally higher relative to wet season flows while the volume (MAR) is the same as PD and almost twice that of the PES requirement. The scenario frequently does not meet the PES or REC requirement in the wet season (i.e. is less than requested), but is more than requirements (and PD) in the dry season.
- Sc C3: Relative to the PD (159 Mm^3) the PES/REC flow requirements are exceeded (160 Mm^3). The scenario is similar to Sc C2 and PD in wet season. Lower flows in dry season relative to Sc C2 (i.e. closer towards natural) but mostly still higher than PD.
- Sc C61: Relative to the PD (159 Mm^3) the PES/REC flow requirements are exceeded (161 Mm^3). The scenario is similar to the PES with higher baseflows throughout the year. The scenario maintained the aquatic biota but impacted the geomorphology and water quality and therefore these two components were assessed.
- Sc C71: Relative to the PD (159 Mm^3) the PES/REC flow requirements are exceeded (161 Mm^3). Similar to Sc C2 and PD in wet season.

Although these volumes of annual flow are in excess of the EWR requirement (at 95 Mm^3) the reversal of seasonality below Kwena Dam is an ecological is the main ecological issue. Currently this is also the case, and to improve the river, less flow during the dry season is required. This reversed flow pattern is indicated in Figure 7.1.

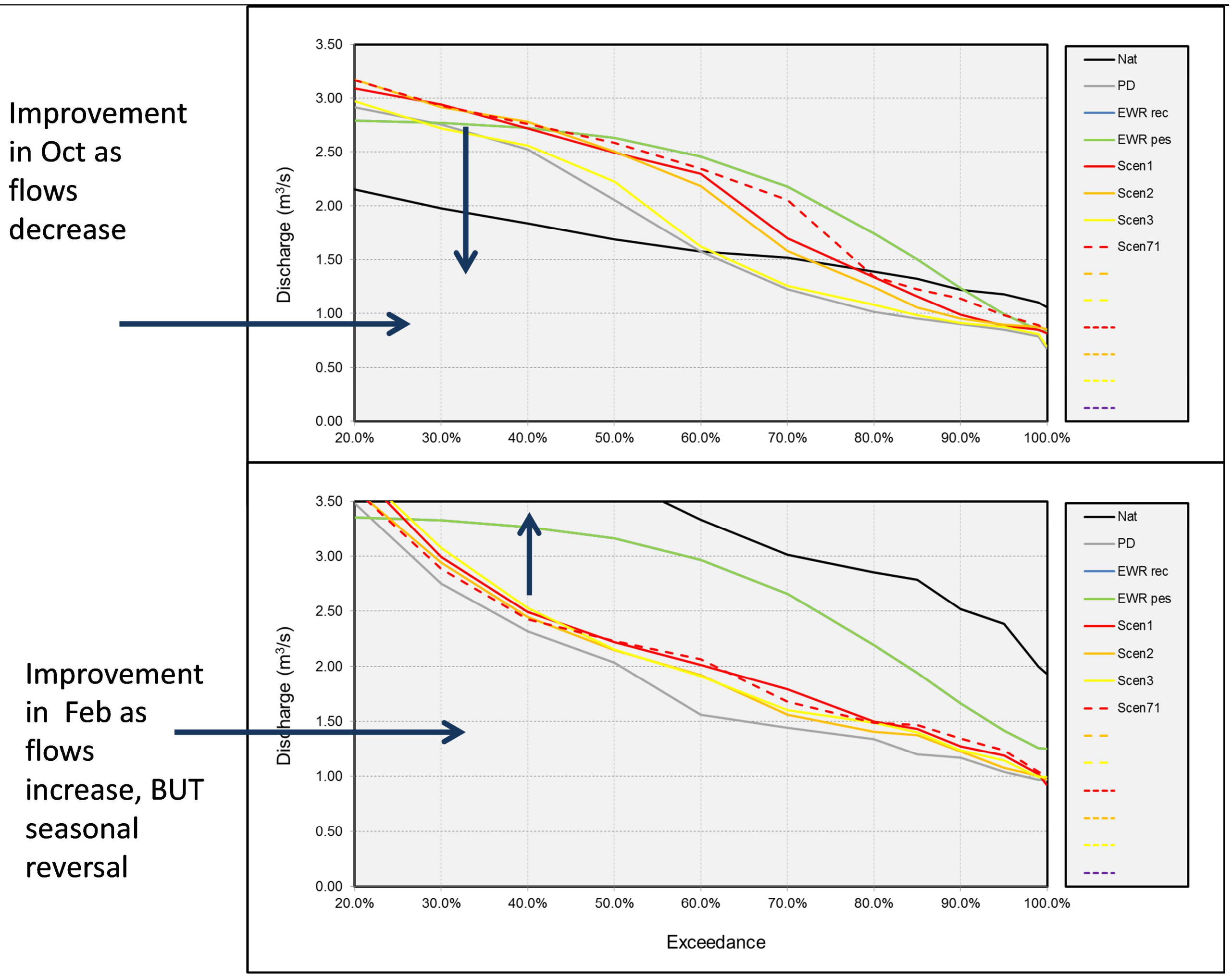

Figure 7.1 The various scenarios during dry and wet season indicating seasonal reversal.

The driver components are summarised in Table 7.1 and the response components in Table 7.2. Summaries are provided in Table 7.3 and Figure 7.2

7.2 CROCODILE EWR C3: ECOLOGICAL DRIVER COMPONENTS

Table 7.1 Crocodile EWR C3: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES (C) (74.7%) and REC (B/C) (78.7%)		
1, 2, 3 71	B (85.6%)	Conditions are similar to Sc 81, but flows are slightly lower in the dry season.
61 81	B (87%)	Flows exceed PES/REC and natural flows most of the time. The higher baseflows throughout the year will result in an improvement in most water quality parameters and an improved overall water quality state.
Geomorphology: PES and REC (C) (64.2%)		
All scenarios	C/D (59.4%)	The geomorphology of the site is in a low C EC. Although high baseflows will be provided, these will be in the dry season, with wet season flows much lower than the PES EWR for this season. Due to the release patterns from Kwena Dam upstream, reduced flood peaks in the wet season and elevated dry season baseflows during the dry season are required to meet irrigation demands. Despite sufficient volumes for the EWRs at the MAR scale for all the scenarios, reduced flood peaks and reduced summer season baseflows all result in smaller, less frequent floods. This reduces scour of the bed, pools and low banks and also promotes vegetation encroachment and channel width reduction (narrowing). The

Sc	EC	Consequences
		scenarios are similar to PD flow conditions and the continued high baseflows through summer and winter will cause further contraction of the riparian zone, resulting in a slow decline in the PES.

7.3 CROCODILE EWR C3: ECOLOGICAL RESPONSE COMPONENTS

The stress indices for fish and macro-invertebrates are provided in Appendix A and should be used in conjunction with the information provided for these components in Table 7.2.

Table 7.2 Crocodile EWR C3: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES and REC (B) (84.7%)		
1	B (84.7%)	Scenario 1 is very similar to the present day flows and therefore estimated to result in similar fish conditions as under PES.
2 3	C (65%)	Although the site currently experience increased (higher) flows in the dry season than wet season (reversed seasonality), under these scenarios the highest dry season flows will occur earlier in the dry season (Jun, compared to Aug under PD conditions). It is therefore feared that the increased high flows so early in the dry season when juvenile fish and fry are still in a very early stage of development, may result in flushing of them downstream. It is therefore estimated that these scenarios will result in deterioration in the fish assemblage of at least one EC to a C.
71	C/D (60%)	Although there is some variation between these two scenarios in terms of flow duration, they are estimated to result in a similar impact on the fish assemblage as Sc C2 and C3. As described for Sc C2 and C3, the earlier dry season high flows may be detrimental to the breeding success (survival) of many juvenile fish. This coupled with geomorphological and marginal vegetation deterioration, as well as the seasonal reversal is expected to have a notable impact on the fish assemblage. It is estimated that the fish assemblage may deteriorate as low as a category C/D.
Macro-invertebrates: PES (C) (74.5%) and REC (B) (84.1%)		
1	C (72.3%)	This scenario is very similar to the present day flows (flows are slightly lower in the dry season), and therefore the stress will not change much and the PES decreases slightly.
2 3	C (68.4%)	Flows are showing reversed seasonality with wet season flows much lower than the PES EWR, reduced flood peaks, and also elevated dry season baseflows. Therefore the stress will increase resulting in a deterioration in the PES.
71	C (67.2%)	Similar to Sc 2 and 3, the flows are showing reversed seasonality (different flow durations) with wet season flows much lower than the PES EWR, reduced flood peaks, and also elevated dry season baseflows. Therefore the stress will increase leading to a deterioration in the PES.
Riparian vegetation: PES (C) (77.3%) and REC (B) (85.1%)		
1	C (64.1%)	Scenario largely similar to Sc C2, C3 and C81. Likely to meet PES but not the REC.
2	C (64%)	Flows are markedly more than natural and the response of vegetation (as a deviation from reference conditions) warrants assessment. Inundation of vegetation is more than PD and the PES and REC requirements in the dry season (snapshot month Jul, 60% duration). The *S. mucronata* population is 75% inundated under PD, 44% under PES and REC and 84% under Sc 2 (bearing in mind that it is naturally predicted to only be 35% inundated under natural flows). Similarly, reeds remain 100% inundated (up to 40 cm) for most of the dry season. Inundation of vegetation is less than the PES and REC requirements in the wet season (Feb 60% duration), similar to PD and half of predicted inundation under natural flows. Nevertheless 49% and 73% of the *S. mucronata* and *Phragmites* populations remain inundated in Feb respectively. The loss of seasonality is likely to promote more defined zoning of vegetation types, together with increased terrestrialisation near the edge of the riparian zone. Increased flows (even more than PD) in the dry season will likely cause additional narrowing of the marginal and lower zones with loss of both woody and non-woody vegetation.
3	C (65.3%)	Vegetation inundation in dry season similar to PD. Inundation of vegetation generally more than PD and less than PES requirement in wet season.

Sc	EC	Consequences
71	C (68.2%)	Vegetation inundation in dry season similar to PD. Inundation of vegetation in wet season similar to Sc C3.

7.4 CROCODILE EWR C3: ECOSTATUS

The resulting ECs for each component and EcoStatus is provided in Table 7.3. The ranking of the scenarios are provided on a traffic diagram (Figure 7.2). The results illustrate that none of the scenarios meet the ecological objectives of the REC. Only Sc C61 maintains the EcoStatus PES although there is deterioration in geomorphology.

Table 7.3 Ecological consequences at CROCODILE EWR C3

Component	PES	REC	Sc C1	Sc C2	Sc C3	Sc C4	Sc C5	Sc C61	Sc C62	Sc C71	Sc C72	Sc C81	Sc C82
Physico chemical	C	B/C	B	B	B	B	B	B	B	B	B	B	B
Geomorphology	C	C	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D
Fish	B	B	B	C	C	C	B	B	C	C/D	C	C/D	C/D
Invertebrates	C	B	C	C	C	C	C	C	C	C	C	C	C
Riparian vegetation	C	B	C	C	C	C	C	C	C	C	C	C	C
EcoStatus	B/C	B	C	C	C	C	C	B/C	C	C	C	C	C

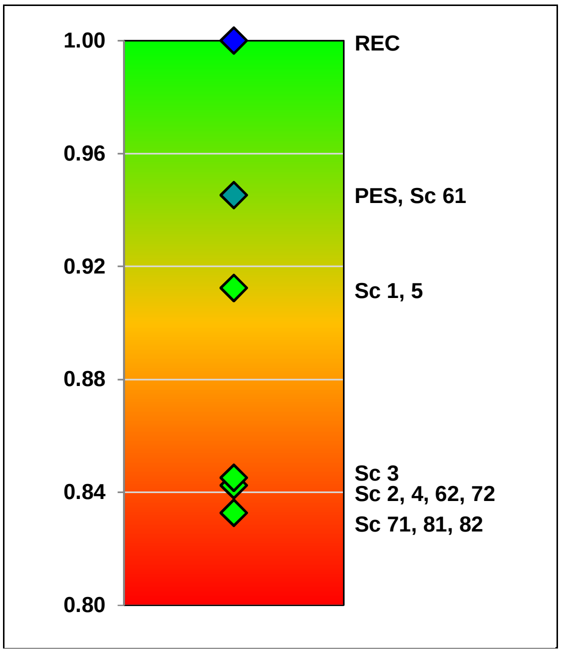

Figure 7.2 Ecological ranking of operational scenarios at CROCODILE EWR C3

8 CROCODILE RIVER SYSTEM (X2) - ECOLOGICAL CONSEQUENCES AT EWR C4 (KANYAMAZANE): CROCODILE RIVER

Scenario C1, C5, C62 and Sc C72 was evaluated at EWR C4. The analysis of the operational scenarios indicated that Sc C1 was similar to Sc C2, C3, C4, C61, C71, C81 and Sc C82 and therefore maintains the PES. All flows under these scenarios are higher than the EWR requirements, as releases are made for irrigation purposes.

8.1 CHANGES IN FLOW REGIME

All the scenarios evaluated in this study provide more flows than the EWR for the PES category during almost all months of the year. At EWR C4, the PD MAR is 537 Mm^3 and volume necessary to achieve the PES is 214 Mm^3. A summary of the effects of the operational scenarios is provided below:

- Sc C5: Relative to the PD (537 Mm^3) it represents a reduction in flow (528 Mm^3). Flows are less than the dry season PES requirement from Apr to Jun for a proportion of the time.
- Sc C62: Relative to the PD (537 Mm^3) it represents more flows (546 Mm^3).
- Sc C72: Relative to the PD (537 Mm^3) it represents a reduction in flow (513 Mm^3). Flows are less than the dry season PES requirement from Apr to Jun for a proportion of the time.

The driver components are summarised in Table 8.1 and the response components in Table 8.2. Summaries are provided in Table 8.3 and Figure 8.1.

8.2 CROCODILE EWR C4: ECOLOGICAL DRIVER COMPONENTS

Table 8.1 Crocodile EWR C: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES (C) (76.7%) and REC (B) (83.3%)		
5 62 72	B (82.8%)	Scenarios are greater than the EWR requirement during low flows, other than May and Jun where they fall below the EWR requirements. Generally conditions will reach the EWR, with resultant improvements in salts and toxics, and a small improvement in nutrient and oxygen levels.
Geomorphology: PES (B/C) (81.6%) and REC (B) (83.5%)		
5 62 72	B/C (81.6%)	The flow regimes across all the scenarios are similar and wet season volumes are more than sufficient to meet the EWR requirements. As there are no very large dams which can inhibit the provision of flood flows this far down the catchment (the impact of altered spills from the upstream Kwena Dam will not have a measureable impact on geomorphology at this site due to amelioration from numerous tributary inputs), moderate and large floods necessary for channel maintenance will still occur. The geomorphology is thus not expected to degrade under the proposed scenarios.

8.3 CROCODILE EWR C4: ECOLOGICAL RESPONSE COMPONENTS

The stress indices for fish and macro-invertebrates are provided in Appendix A and should be used in conjunction with the information provided for these components in Table 8.2.

Table 8.2 Crocodile EWR C4: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES and REC (B) (84.2%)		
5	A/B (90%)	When comparing this scenario with the PES EWR flows, it is evident that there will be decreased stress on fish under both maintenance (70%) and especially in drought (95%)

Sc	EC	Consequences
		flows. There may potentially be slightly increased stress in the wet season months of Mar and Apr (based on low flows only), but overall the flow regime is estimated to reduce stress on the fish assemblage. This improvement is further enhanced by improved water quality as well as slightly better marginal vegetation habitats. It is therefore estimated that the fish will improve.
62	A (95%)	Conditions in terms of flow will be even better (reduced stress) and with the coupled improvement of water quality and marginal vegetation it is estimated that the fish assemblage may be in a near natural state.
72	A (93%)	Conditions will be very similar to Sc C5, but even more reduced stress in the drought season may result in a further improvement in the fish assemblage, now falling in a category A.
Macro-invertebrates: PES (C) (75.9%) and REC (B) (84.3%)		
5	B (84.1%)	Most of the flows improve during the maintenance and drought periods, resulting in a decrease in stress and therefore an improvement of the PES.
62	A/B (88.1%)	Most of the flows improved during the maintenance and drought periods, resulting in a decrease in the stress. Most of the months have lower stress, between a 1 and 2, resulting in an improvement in the PES.
72	A/B (91%)	Most of the flows improve during the maintenance and drought periods, resulting in a decrease in stress and therefore an improvement of the PES.
Riparian vegetation: PES (C) (64.7%) and REC (B) (83.1%)		
5 72	C (64.7%)	These scenarios are less than the dry season PES requirement Apr to Jun for a proportion of the time. This results in less inundation of marginal and lower zone vegetation (mainly reeds, sedges and dicotyledonous hydrophilic species; refer to spreadsheet), but the reduction is not enough to elicit a response that will alter the EC.
62	C (70.3%)	Results in small improvement of the EC due to increased inundation of marginal and lower zone vegetation, likely to favour non-woody species and may reduce some alien species abundance in the area of frequent inundation.

8.4 CROCODILE EWR C4: ECOSTATUS

The resulting ECs for each component and EcoStatus is provided in Table 8.3. The ranking of the scenarios are provided on a traffic diagram (Figure 8.1). The results illustrate that all the scenarios meet the ecological objectives of the PES and of these scenarios; Sc C62 and C72 result in an improvement in the PES, although the REC requirements are not met. This site is upstream of the major off-takes into canals for irrigation further downstream and the problems (current and with scenarios) are the constraints on the operation for irrigation resulting in an unseasonal distribution of flows.

Table 8.3 Ecological consequences at CROCODILE EWR C4

Component	PES	REC	Sc C1	Sc C2	Sc C3	Sc C4	Sc C5	Sc C61	Sc C62	Sc C71	Sc C72	Sc C81	Sc C82
Physico chemical	C	B	C	C	C	C	B	C	B	C	B	C	C
Geomorphology	B/C	B	B/C	B/C	B/C	B/C	B/C	B/C	B/C	B/C	B/C	B/C	B/C
Fish	B	B	B	B	B	B	A/B	B	A	B	A	B	B
Invertebrates	C	B	C	C	C	C	B	C	A/B	C	A/B	C	C
Riparian vegetation	C	B	C	C	C	C	C	C	C	C	C	C	C
EcoStatus	C	B	C	C	C	C	C	C	B/C	C	B/C	C	C

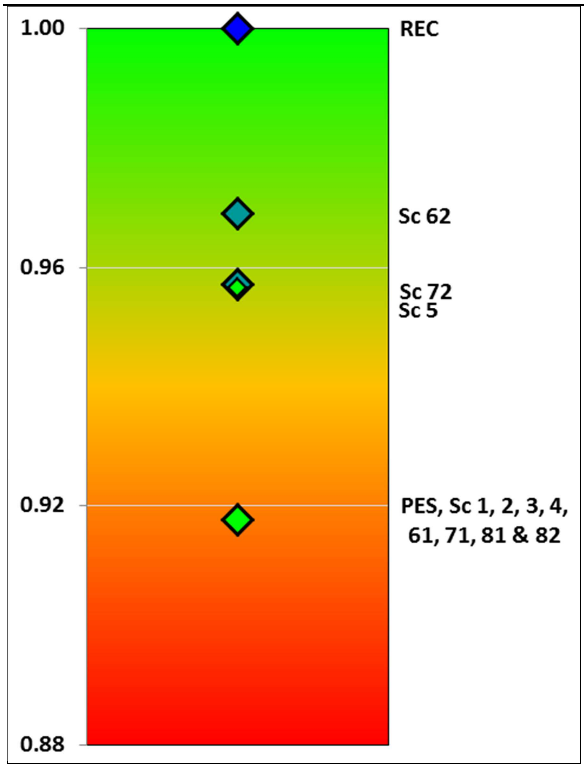

Figure 8.1 Ecological ranking of operational scenarios at CROCODILE EWR C4

9 CROCODILE RIVER SYSTEM (X2) - ECOLOGICAL CONSEQUENCES AT EWR C5 (MALELANE): CROCODILE RIVER

Scenario C1, C2, C5 and Sc C82 was evaluated at EWR C5. The analysis of the operational scenarios indicated that Sc C2 was similar to Sc C4, C61, C71 and C81 while Sc C5 was similar to Sc C62, and Sc C72. Scenario C2 and Sc C5 therefore represent these scenarios respectively. Scenario C3 was not evaluated as it was similar to the PES requirements.

9.1 CHANGES IN FLOW REGIME

All the scenarios evaluated in this study provide more flows than the EWR for the PES category during almost all months of the year. At EWR C5, the PD MAR is 654 Mm^3 and volume necessary to achieve the PES is 304 Mm^3.A summary of the effects of the operational scenarios is provided below:

- Sc C1: Relative to the PD (654 Mm^3) the scenario represents a decrease in flows (637 Mm^3). Stream permanency remains at 100% and does not exceed natural flows. Seasonality is similar to PD. This scenario meets the PES requirement for most months except in the dry season from May to Aug, and meets the REC for some of the time in some months (mainly wet season).
- Sc C2: Relative to the PD (654 Mm^3) the scenario represents an increase in flows (744 Mm^3). The scenario is similar to the REC requirements in Oct; however flows are lower during May and June. The scenario was assessed to determine if the REC requirements would be met.
- Sc C5: Relative to the PD (654 Mm^3) the scenario represents a decrease in flows (635 Mm^3). Stream permanency remains at 100% and does not exceed natural flows. Seasonality is similar to PD, although flows are less than PD and the PES requirement in the dry season. The PES requirement is generally met in the wet season.
- Sc C82: Relative to the PD (654 Mm^3) the scenario represents a decrease in flows (650 Mm^3). Stream permanency remains at 100% and does not exceed natural flows. Seasonality is similar to PD and meets the REC requirement in the wet season. Under this scenario the REC is met at times during the dry season and the PES at other times and essentially lies between the PES and REC requirements.

The driver components are summarised in Table 9.1 and the response components in Table 9.2. Summaries are provided in Table 9.4 and Figure 9.1.

9.2 CROCODILE EWR C5: ECOLOGICAL DRIVER COMPONENTS

Table 9.1 Crocodile EWR C5: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES (C) (67.2%) and REC (B) (83.6%)		
2 82	B/C (81.2%)	These scenarios exceed the PES and REC most of the time in the dry flow period, with little changes to floods. Some improvement in present state may be seen for all parameters.
1	C (67.8%)	Conditions are expected to stay unchanged from PD.
5	C (65.0%)	Conditions are very similar to Sc C1, but a small impact on nutrients and temperature is expected under low flows.
Geomorphology: PES (C/D) (60.1%) and REC (C) (64.4%)		
1 2 5	C/D (60.1%)	The flow regimes across all the scenarios are similar and wet season volumes are more than sufficient to meet the EWR requirements, especially since the C/D condition of the geomorphology at this site did not warrant the provision of many floods. As there are no

Sc	EC	Consequences
82		very large dams which can inhibit the provision of flood flows this far down the catchment (the impact of altered spills from the upstream existing Kwena and potential Kaap River dams will not have a measureable impact on geomorphology at this site due to amelioration from numerous tributary inputs), and moderate and large floods necessary for channel maintenance will still occur. The geomorphology is thus not expected to degrade under the proposed scenarios.

9.3 CROCODILE EWR C5: ECOLOGICAL RESPONSE COMPONENTS

The stress indices for fish and macro-invertebrates are provided in Appendix A and should be used in conjunction with the information provided for these components in Table 9.2.

Table 9.2 Crocodile EWR C5: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES (C) (66.1%) and REC (B) (84.9%)		
1	C (63%)	Conditions are expected to be very similar to the PES (EWR); however the slight increase in stress in the dry months may result in a slight deterioration in the fish assemblage. It is however thought that the fish will remain in a category C, albeit slightly lower and bordering on a C/D.
2 82	B (82%)	Flows are notably better than under the PES (EWR) and hence decreased stress will be experienced throughout all seasons under maintenance and drought conditions. The improvement in flows and hence habitat conditions will be further enhanced by improved water quality. An improvement in the overall status of the fish assemblage is therefore expected and the REC should be attained.
5	C (65%)	Conditions are very similar to Sc C1 and slightly lower than the PES (EWR) requirements. It is therefore estimated that the EC will remain in the PES albeit only slightly lower.
Macro-invertebrates: PES (C) (76.9%) and REC (B) (86.3%)		
1	C (73.2%)	The vegetation parameters deteriorated marginally, and most of the low flows (maintenance), result in an increase of stress (1) resulting in a deterioration of the PES.
2	B (85.1%)	Compared with the PES, water quality parameters, vegetation aspects and most of the flows improved during the maintenance and drought periods, resulting in a decrease in the stress and overall improvement in the PES and maintaining REC requirements.
5	C (75%)	Similar to Sc C1, however, vegetation parameters and water quality deteriorated marginally and most of the wet season low flows (maintenance) results in increased stress (1). The PES deteriorates marginally.
82	B (84.7%)	Similar to Sc C2 with improvement in water quality parameters. Vegetation aspects and most of the flows improved during the maintenance and drought periods, resulting in decreased stress. Thus the PES will improve to a B (84.7%).
Riparian vegetation: PES (C) (76.3%) and REC (B) (83%)		
1	No change	Inundation of the marginal zone vegetation in the dry season (snapshot taken of May at 60% duration) is less than the PES requirement (especially sedges) but more than PD. This equates to an estimated reduction of about 10% of inundated marginal zone vegetation, but stage drops generally about 6 cm so no measurable response by vegetation is expected.
2	B/C (78.7%)	The REC is almost achieved, but without non-flow related management as well it is not fully achieved. Inundation of the marginal zone vegetation is markedly more in the dry season.
5	C (74.2%)	The PES requirement is generally met in the wet season. Inundation of the marginal zone vegetation is less than the PES requirement in the dry season and at times also less than PD. The EC score deteriorates slightly but remains in a Category C.
82	B/C (79.4%)	Results in increased inundation of the marginal and lower zone vegetation relative to PD and at times the PES. The REC is almost achieved, but without additional non-flow related management (alien vegetation and vegetation clearing on the right bank) it is not fully achieved.

9.4 CROCODILE EWR C5: ECOSTATUS

The resulting ECs for each component and EcoStatus is provided in Table 9.3. The ranking of the scenarios are provided on a traffic diagram (Figure 9.1). The results illustrate that most of the scenarios meet the ecological objectives of the PES and of these scenarios; Sc C2, C4. C61, C71, C81 and C82 result in an improvement in the PES, although the REC requirements are not met. Scenario C1, C5, C62 and C72 result in the PES EcoStatus although low flows is lower than the PES requirement.

Table 9.3 Ecological consequences at CROCODILE EWR 5

Component	PES	REC	Sc C1	Sc C2	Sc C3	Sc C4	Sc C5	Sc C61	Sc C62	Sc C71	Sc C72	Sc C81	Sc C82
Physico chemical	C	B	C	B/C	C	B/C	C	B/C	C	B/C	C	B/C	B/C
Geomorphology	C/D	C	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D
Fish	C	B	C	B/C	C	B/C	C	B/C	C	B/C	C	B/C	B/C
Invertebrates	C	B	C	B	C	B	C	B	C	B	C	B	B
Riparian vegetation	C	B	C	B/C	C	B/C	C	B/C	C	B/C	C	B/C	B/C
EcoStatus	C	B	C	B/C	C	B/C	C	B/C	C	B/C	C	B/C	B/C

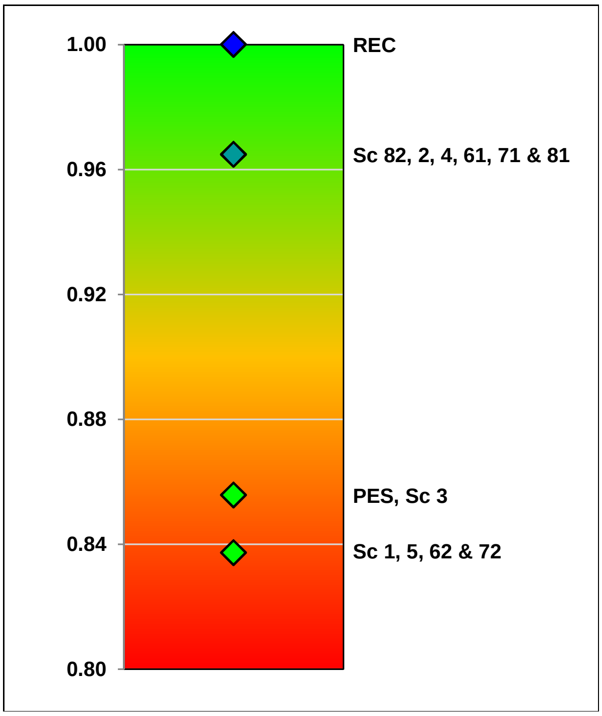

Figure 9.1 Ecological ranking of operational scenarios at CROCODILE EWR C5

10 CROCODILE RIVER SYSTEM (X2) - ECOLOGICAL CONSEQUENCES AT EWR C6 (NKONGOMA): CROCODILE RIVER

Scenario C1, C2, C5 and Sc C82 was evaluated at EWR C6. The analysis of the operational scenarios indicated that the following scenarios were similar:

- Sc C82 was similar to Sc C3 and Sc C62.
- Sc C5 was similar to Sc C72.
- Sc C4 was similar to Sc C61, C71 and Sc C81.

Therefore Sc C3, C4 and Sc C5 represent these scenarios respectively. Scenario C4 and associated scenarios were not evaluated as it was similar to the REC requirements, i.e. the consequences are known.

10.1 CHANGES IN FLOW REGIME

All the scenarios evaluated in this study provide more flows than the EWR for the PES category during almost all months of the year. At EWR C6, the PD MAR is 570 Mm^3 and volume necessary to achieve the PES and REC is 18.1 Mm^3. A summary of the effects of the operational scenarios is provided below:

- Sc C1: Relative to the PD (570 Mm^3) the scenario represents a decrease in flows (562 Mm^3). Stream permanency is 100% and natural flows are never exceeded. The volume (MAR) is the same as PD and twice the PES requirement. This scenario provides improved seasonality towards the PES requirement. Wet season flows generally meet the PES requirement (Feb) while dry season flows (Jul) are generally better than PD but do not meet the PES requirement for most of the time.
- Sc C2: Relative to the PD (570 Mm^3) the scenario represents an increase in flows (722 Mm^3). An overall improvement in flows during the dry and wet season is expected.
- Sc C5: Relative to the PD (570 Mm^3) the scenario represents a decrease in flows (565 Mm^3). Stream permanency is 100% and natural flows are never exceeded. The volume (MAR) is the same as PD and twice the PES requirement. Seasonality – the range between high and low flows are increased, which is a trend away from natural or the PES requirement. Wet season flows generally meet the PES requirement (Feb) while dry season flows (Jul) are better than PD and meet the PES requirements.
- Sc C82: Relative to the PD (570 Mm^3) the scenario represents an increase in flows (585 Mm^3). Stream permanency is 100% and natural flows are never exceeded. The volume (MAR) is the same as PD and twice the PES requirement. Seasonality – the range between high and low flows are increased, which is a trend away from natural or the PES requirement. Wet season flows generally meet the PES requirement (Feb) while dry season flows (Jul) are generally similar to or less than PD and never meet the PES requirement.

The driver components are summarised in Table 10.1 and the response components in Table 10.2. Summaries are provided in Table 10.4 and Figure 10.1.

10.2 CROCODILE EWR C6: ECOLOGICAL DRIVER COMPONENTS

Table 10.1 Crocodile EWR C6: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES (C) (67.5%) and REC (B) (83%)		
1 82	C (63.8%)	The flow regimes across these the scenarios are similar for the high flows and wet season volumes are more than sufficient to meet the EWR requirements. However, some impact is seen under low flow conditions with Sc C82 flows being well below PES and REC. An impact is expected on nutrient, salt and temperature conditions at low flows.
2	B (82.6%)	The flow regimes across these the scenarios are similar for the high flows and wet season volumes are more than sufficient to meet the EWR requirements. Low flow baseflows are similar to the REC. An improvement is seen across all water quality parameters.
5	C/D (58.6%)	Low flow conditions are well below PES and the REC. There are reduced wet season flows, with conditions a bit worse under Sc C72. Impacts on water quality are expected for salts, nutrients and oxygen.
Geomorphology: PES and REC (C) (66.6%)		
1 2 82	C (66%)	The flow regimes across these the scenarios are similar and wet season volumes are more than sufficient to meet the EWR requirements, especially as the C condition of the geomorphology at this site did not warrant the provision of many floods. As there are no very large dams which can inhibit the provision of flood flows this far down the catchment (the impact of altered spills from the upstream existing Kwena and potential Kaap River dams will not have a measureable impact on geomorphology at this site due to amelioration from numerous tributary inputs), moderate and large floods necessary for channel maintenance will still occur. The geomorphology is thus not expected to degrade.
5	C/D (58.8%)	The reduced wet season flows are below the PES EWR for portions of the wet season. These flows will be unable to meet the small and moderate flood requirements of the site, and thus, due to reduced transport and scour of the sediments in the channel, would result in a reduced inchannel and bank condition.
72	D (55.3%)	The reduced wet season flows are below the PES EWR (and below Sc C5) for portions of the wet season. These flows will be unable to meet the small and moderate flood requirements of the site, and thus, due to reduced transport and scour of the sediments in the channel, would result in a reduced inchannel and bank condition.

10.3 CROCODILE EWR C6: ECOLOGICAL RESPONSE COMPONENTS

The stress indices for fish and macro-invertebrates are provided in Appendix A and should be used in conjunction with the information provided for these components in Table 10.2.

Table 10.2 Crocodile EWR C6: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES (C) (65.6%) and REC (B) (84.9%)		
1 5	D (48%)	It is evident that under these scenarios the decreased flows will result in notable increased tress on the fish assemblage. Although the stress increase will generally be minimal (1 stress) during the dry season, the wet season will be notably worse under these scenarios (especially during Feb and Mar). These months are especially important periods for fish functions such as spawning, breeding, nursery and migration that will be impacted negatively and together with an expected decrease in water quality (and geomorphology under Sc C5); the fish assemblage is expected to decrease towards a lower EC of a D.
2	C (76%)	Reduced stress (increased flow) on fish assemblages will be evident in both wet and dry season months (especially dry season) and under both drought and maintenance flows. This, coupled with an improvement in water quality, it can be expected to result in an overall improvement in the ecological integrity to a higher level within the same EC.
82	C/D (60%)	The dry season flows will be adequate to maintain similar stress than under the PES (EWR), but the wet season is exerted to increased stress levels (especially during Feb

Sc	EC	Consequences
		and Mar). This together with the slight deterioration in geomorphology and water quality it is estimated to result in a reduction in the PES.
Macro-invertebrates: PES (C) (74.9%) and REC (B) (83.7%)		
1 5	D (50.2%)	The geomorphology indicates that the flood requirements might not be met and this will reduce inchannel and bank condition. Water quality will be impacted (lower than PES), but the vegetation parameters will not be impacted significantly. Most of the flows (maintenance and drought), result in a stress of 1 - 4 and a deterioration is expected.
2	B/C (79.3%)	An improvement is seen across all water quality parameters, but the vegetation parameters will not change from the PES. Most of the flows improve during the maintenance and drought periods, resulting in a decrease in stress. Thus an improvement in the PES is expected.
82	C (68.8%)	Water quality will be impacted (lower than PES), but the vegetation parameters will not be impacted significantly. Most of the flows will maintain a similar stress than under PES (EWR), but the wet season is exerted to increased stress levels and the PES will deteriorate within the PES Category.
Riparian vegetation: PES (C) (76.6%) and REC (B) (86.7%)		
1	B/C (80.2%)	Inundation of vegetation is generally more than PD but less than the PES requirement in the dry season (snapshot month July, 60% duration) e.g. the *C. marginatus* (sedge) population is 4% inundated under PD, 80% under the PES and 36% under Sc C1. Similarly, reeds are 28% inundated under PD, 43% under the PES and 34% under Sc C1. Inundation of vegetation is more than PD, the same as the PES requirement and less than the REC requirement in the wet season (Feb, 60% duration). Sedges remain 100% inundated (up to 50 cm) while reeds remain 70% inundated (up to 90 cm). Marginal zone vegetation is likely to recede slightly with increased (improved) low flows, especially in the dry season. Unlikely to affect woody species.
5	C (74%)	Inundation of vegetation is generally the same as PD and substantially less than the PES requirement in the dry season (snapshot month July, 60% duration) e.g. the *C. marginatus* (sedge) population is 4% inundated under PD and Sc 5 and 80% under the PES requirement. Similarly, reeds are 28% inundated under PD and Sc C5 and 43% under the PES. Inundation of vegetation is the same as PD, and less than the PES and REC requirements in the wet season (Feb, 60% duration). Sedges remain 100% inundated (up to 50 cm) while reeds remain 68% inundated (up to 84 cm). Small change as non-woody vegetation encroaches slightly towards channel.
82	B (82.5%)	Inundation of vegetation is substantially more than PD and slightly more than the PES requirement in the dry season (snapshot month July, 60% duration) e.g. the *C. marginatus* (sedge) population is 4% inundated under PD, 80% under PES and 89% under Sc C82. Similarly, reeds are 28% inundated under PD, 43% under the PES and 44% under Sc C82. Inundation of vegetation is the same as PD and less than the PES and REC requirements in the wet season (Feb, 60% duration). Sedges remain 100% inundated (up to 50 cm) while reeds are 68% inundated (up to 84 cm). Marginal zone vegetation likely to recede slightly with increased (improved) low flows, especially in the dry season. Unlikely to affect woody species.

10.4 CROCODILE EWR C6: ECOSTATUS

The resulting ECs for each component and EcoStatus is provided in Table 10.3. The ranking of the scenarios are provided on a traffic diagram (Figure 10.1). The results illustrate that Sc C5 and Sc C72 do not meet the ecological objectives of the PES or the REC. Sc C4, C61, C71 and Sc C81 meet the REC requirements. Sc C2 also meets the REC requirements although the ecological objectives for macro-invertebrates are not fully met. Scenario C1, C3, C62 and Sc C82 meet the PES requirements however the instream biota are impacted to a greater extent under these scenarios and ecological objectives are not fully met for fish and macro-invertebrates.

Table 10.3 Ecological consequences at CROCODILE EWR C6

Component	PES	REC	Sc C1	Sc C2	Sc C3	Sc C4	Sc C5	Sc C61	Sc C62	Sc C71	Sc C72	Sc C81	Sc C82
Physico chemical	C	B	C	B	C	B	C/D	B	C	B	C/D	B	C
Geomorphology	C	C	C	C	C	C	C/D	C	C	C	D	C	C
Fish	C	B	D	C	C/D	B	D	B	C/D	B	D	B	C/D
Invertebrates	C	B	D	B/C	C	B	D	B	C	B	B	B	C
Riparian vegetation	C	B	B/C	B	B	B	C	B	B	B	C	B	B
EcoStatus	C	B	C	B	C	B	C/D	B	C	B	C/D	B	C

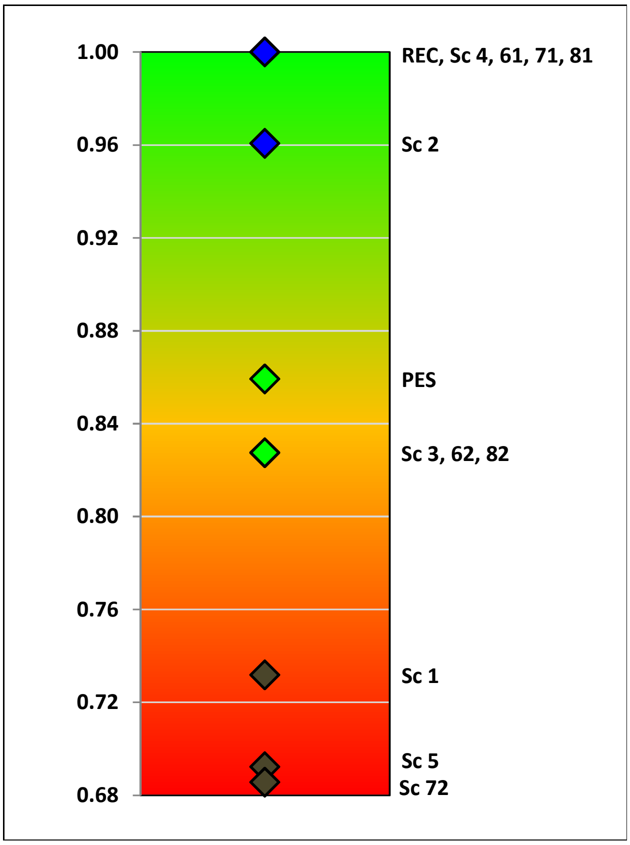

Figure 10.1 Ecological ranking of operational scenarios at CROCODILE EWR C6

11 CROCODILE RIVER SYSTEM (X2) - ECOLOGICAL CONSEQUENCES AT EWR K7 (HONEYBIRD): KAAP RIVER

Scenario C1, C2, C81 and Sc C62 was evaluated at EWR K7. The analysis of the operational scenarios indicated that the following scenarios were similar:

- Sc C1 was similar to Sc C5, C62, C72 and C82.
- Sc C2 was similar to Sc C4.
- Sc C81 was similar to Sc C3, C61, and C71.

Therefore Sc C1, C2 and Sc C81 represent these scenarios respectively.

11.1 CHANGES IN FLOW REGIME

At EWR K7, the PD MAR is 89 Mm^3 and the volume necessary to achieve the PES is 39 Mm^3, with 48 Mm^3 required to achieve the REC. A summary of the effects of the operational scenarios is provided below:

- Sc C1: Relative to the PD (89 Mm^3) the scenario represents similar flows (89 Mm^3). Stream permanency is less than natural and both the PES and REC requirement; similar to PD at 83%. Natural flows are never exceeded. Seasonality is similar to the PES requirement and the volume (MAR) the same as PD and twice that of PES and REC requirement. The scenario meets the PES requirement for most of the time in the wet season, but not in the dry season.
- Sc C2: Relative to the PD (89 Mm^3) the scenario represents an increase in flows (107 Mm^3). Flow conditions are higher than PD, tending towards more natural baseflow conditions. The scenario is similar to Sc C81 with better flows and an overall improvement in flows during the dry and wet season is expected.
- Sc C81: Relative to the PD (89 Mm^3) the scenario represents an increase in flows (103 Mm^3). Flow conditions are higher than PD, tending towards more natural baseflow conditions. Stream permanency is less than Natural and the PES requirement at 95%. Natural flows are never exceeded and seasonality is better than PD and similar to the PES requirement. The volume is slightly less than Sc C2. More flows are provided than under PD in the dry season but only meets the PES requirement about 50 to 60% of the time. Generally the scenario is the same as PD or better in the wet season and frequently meets either the PES or REC requirement, but not always (especially at high percentiles).

The driver components are summarised in Table 11.1 and the response components in Table 11.2. Summaries are provided in Table 11.4 and Figure 11.1.

11.2 CROCODILE EWR K7: ECOLOGICAL DRIVER COMPONENTS

Table 11.1 Crocodile EWR K7: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES and REC (B) (86.8%)		
1	C (64.6%)	Low flow conditions are slightly worse than Sc C81, although high flows are similar to PD so flushing flows will still be present in the system. Salts and nutrient levels are expected to increase slightly.
2	B (82.6%)	Conditions maintain the present state for water quality.
81 82	C (67.2%)	A significant impact on water quality will be seen, with flows being well below the PES and REC during the dry season. Impacts are therefore expected for most water quality variables. High flows are similar to PD so flushing flows will still be present in the system. Mining effluents will be caught in the dam, with a nutrient build-up downstream

Sc	EC	Consequences
		of the dam due to agricultural activities in the area. It is assumed that Mountain View Dam will be operated as a multi-level off-take dam.
Geomorphology: PES and REC (B) (86.1%)		
1 2 81	B (86%)	These flow scenarios, provides the same or greater flow volumes than the PD to the site. The volumes are available to meet the PES EWR requirements for high wet season baseflows and small flood for high flows. Moreover, the bedrock controlled nature of the site makes it resilient to flow changes. There may be some slight channel encroachment if very large floods are reduced, but no EC change in the PES is expected under these scenarios.

11.3 CROCODILE EWR K7: ECOLOGICAL RESPONSE COMPONENTS

The stress indices for fish and macro-invertebrates are provided in Appendix A and should be used in conjunction with the information provided for these components in Table 11.2.

Table 11.2 Crocodile EWR K7: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES (C) (76.8%) and REC (B) (86.8%)		
1	D (56%)	Flows and hence stress on the fish is notably higher during both the wet and dry seasons under maintenance and drought conditions. Increased stress is especially evident during Jun - Aug (maintenance flows). This, coupled with potential water quality deterioration as well as decrease in marginal vegetation as cover is estimated to result in a notable deterioration in the fish assemblage. The migratory impact of the proposed dam can be expected to further decrease the fish ecological state, falling in an overall Category D.
2	B (82.2%)	Reduced stress in both wet and dry seasons (most months) under both maintenance and drought flows. This improvement is estimated to result in an overall improvement in the fish assemblage that may reach the REC of a B.
81	C (68%)	The scenario will all have similar to slightly higher stress (especially under maintenance conditions) than the PES (EWR). It is therefore estimated that the status of the fish assemblage may be reduced but remain within the same (C) EC as the PES.
Macro-invertebrates: PES and REC (B) (83.6%)		
1	C/D (58.9%)	Compared with the PES, changes in the geomorphology (very large floods are reduced), and water quality (salts and nutrient levels increase) are evident although vegetation parameters are unimpacted. Flows are impacted during both the wet and dry seasons under maintenance and drought conditions causing the PES to deteriorate slightly.
2	B/C (80.5%)	Compared with the PES, changes are evident in geomorphology (slight channel encroachment) and water quality (nutrient build-up downstream), but not the vegetation parameters are impacted. During the low flows some stress is experienced, causing the PES to deteriorate slightly.
81	B (83.6%)	Compared with the PES, changes are evident in geomorphology slight channel encroachment), and nutrient build-up downstream occurs although no vegetation parameters are impacted. The PES should be maintained under these conditions.
Riparian vegetation: PES (C/D) (59.7%) and REC (B/C) (80.5%)		
1	C/D (59.7%)	As with PD and the PES requirement, inundation of the marginal zone vegetation (mostly reeds) is about 20 cm (snapshot in June, 60% duration) with the upper limit of the population still less than 0.5 m higher than water level. In the wet season, large portions of reeds remain inundated (up to 40 cm), slightly less than PD and the PES requirement. The upper limit of reeds however remains under 0.5 m and persistence and vigour is likely.
2 81	C/D (59.7%)	In the dry (June, 60% duration) and wet season (Feb, 60% duration) reed inundation is the same as the PES requirement.

11.4 CROCODILE EWR K7: ECOSTATUS

The resulting ECs for each component and EcoStatus is provided in Table 11.3. The ranking of the scenarios are provided on a traffic diagram (Figure 11.1). The evaluation against EWR was made based on the assumption that the EWR should not be higher than PD flows during the dry season. All scenarios meet the PES or marginally improve the PES (Sc C2 and C4) except for Sc C72 results in a drop in most categories and results in a C/D EcoStatus. The reason for the lower EC is due to lower flows than the EWR and the PD during the dry months which impacts on the WQ and instream biota. Of these scenarios, Sc C2 and C4 are the best scenarios.

Table 11.3 Ecological consequences at CROCODILE EWR K7

Component	PES	REC	Sc C1	Sc C2	Sc C3	Sc C4	Sc C5	Sc C61	Sc C62	Sc C71	Sc C72	Sc C81	Sc C82
Physico chemical	B	B	B	B	B	B	B	B	B	B	C	B	B
Geomorphology	B	B	B	B	B	B	B	B	B	B	B	B	B
Fish	C	B	C	B	C	B	C	C	C	C	D	C	C
Invertebrates	B	B	B	B/C	B	B/C	B	B	B	B	C/D	B	B
Riparian vegetation	C/D	B/C	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D
EcoStatus	C	B	C	C	C	C	C	C	C	C	C/D	C	C

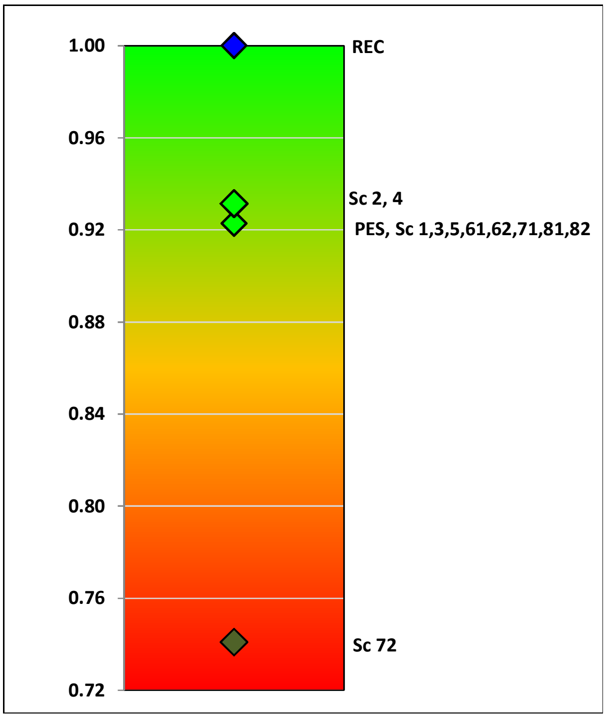

Figure 11.1 Ecological ranking of operational scenarios at CROCODILE EWR K7

12 KOMATI CATCHMENT (X1) - ECOLOGICAL CONSEQUENCES AT EWR K3 (TONGA): KOMATI RIVER

All scenarios were grouped together and Sc 43 was selected to be evaluated as representative of all the scenarios. Scenario K43 has marginally more zero flows than the other scenarios.

12.1 CHANGES IN FLOW REGIME

The PD MAR is 319 Mm^3 and volume necessary to achieve the PES is 102 Mm^3. Under Sc K43 stream permanency is less than Natural (which is 100%) and slightly less than the PES requirement and PD. Flows never exceed natural and seasonality is similar to PD. The wet season is similar to PD and the dry season is also similar to PD except for drought flows which are generally less, with additional zero flows.

The driver components are summarised in Table 12.1 and the response components in Table 12.2. Summaries are provided in Table 12.3 and Figure 12.1.

12.2 KOMATI EWR K3: ECOLOGICAL DRIVER COMPONENTS

Table 12.1 Komati EWR K3: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES C/D (60.2%) and REC C/D		
43	C (68.2%)	Conditions are improved from a PES of a C/D as baseflows are higher than PES throughout the year, although flows do still drop to zero in October. Water quality state is therefore expected to improve, particularly for nutrients, salts, temperature and oxygen.
Geomorphology: PES and REC (D/E) (40%)		
43	D (45%)	The low PES for geomorphology (D/E category) of the 2006 EWR study is supported by the E category of the river determined in the DWA PES-EIS assessments of 2011 for this (X13J-01130) and the upstream (X13J-01149) sub-quaternary catchments. The low PES is due to inundation from weirs, catchment erosion, riparian vegetation removal and loss of floods. Some of the high flows will be reinstated and this will result in an increase in the EC to a D.

12.3 KOMATI EWR K3: ECOLOGICAL RESPONSE COMPONENTS

Table 12.2 Komati EWR K3: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES and REC (C/D) (60.5%)		
43	C (63%)	When considering the total flows at the site, there will be notably less stress on fish during most of the wet and dry season months during maintenance and drought conditions. When only considering the low (base) flows, there seems to be a slight increase in stress in most wet season months (drought and maintenance flows) while the stress in the dry season months will be mostly unchanged. Although slight improvement in water quality and geomorphology is expected, the potential improvement of these factors may be negated by the potential increased stress of the wet seasons (lower base flows) which may cause the fish to remain in the PES of a C/D. Since the total flows, which may be a better reflection of the actual conditions in the wet season as floods play an important role in the provision and maintenance of habitat for fish, indicate improved condition (decreased fish stress), it can be assumed that the fish may in fact improve slightly towards a Category C.
Macro-invertebrates: PES and REC (D) (55.2%)		
43	C/D	Compared with the PES, some of the high flows increased as well as base flows,

Sc	EC	Consequences
	(58%)	although zero-flows still occur. Adverse conditions in the geomorphology such as inundation from weirs, catchment erosion, and riparian vegetation removal still prevail, however water quality improves and vegetation parameters remain stable. Somewhat lower stress is experienced due to improvement in the overall flow situation, resulting in an improvement.
Riparian vegetation: PES (D/E) and REC (D) (51.1%)		
43	D (51.1%)	No change in riparian vegetation is expected.

12.4 KOMATI EWR K3: ECOSTATUS

The resulting ECs for each component and EcoStatus is provided in Table 12.3. The ranking of the scenarios are provided on a traffic diagram (Figure 12.1). The results illustrate that all the scenarios meet the ecological objectives. Scenario K43 is the best scenario as it results in improved conditions for all the components except riparian vegetation which remains stable.

Table 12.3 Ecological consequences at KOMATI EWR K3

Component	PES	REC	Sc K1	Sc K2	Sc K6	Sc K31	Sc K32	Sc K41	Sc K42	Sc K43
Physico chemical	C/D	C/D	C	C	C	C	C	C	C	C
Geomorphology	D/E	D	D	D	D	D	D	D	D	D
Fish	C/D	C/D	C	C	C	C	C	C	C	C
Invertebrates	D	D	C/D	C/D	C/D	C/D	C/D	C/D	C/D	C/D
Riparian vegetation	D	D	D	D	D	D	D	D	D	D
EcoStatus	D	D	D	D	D	D	D	D	D	D

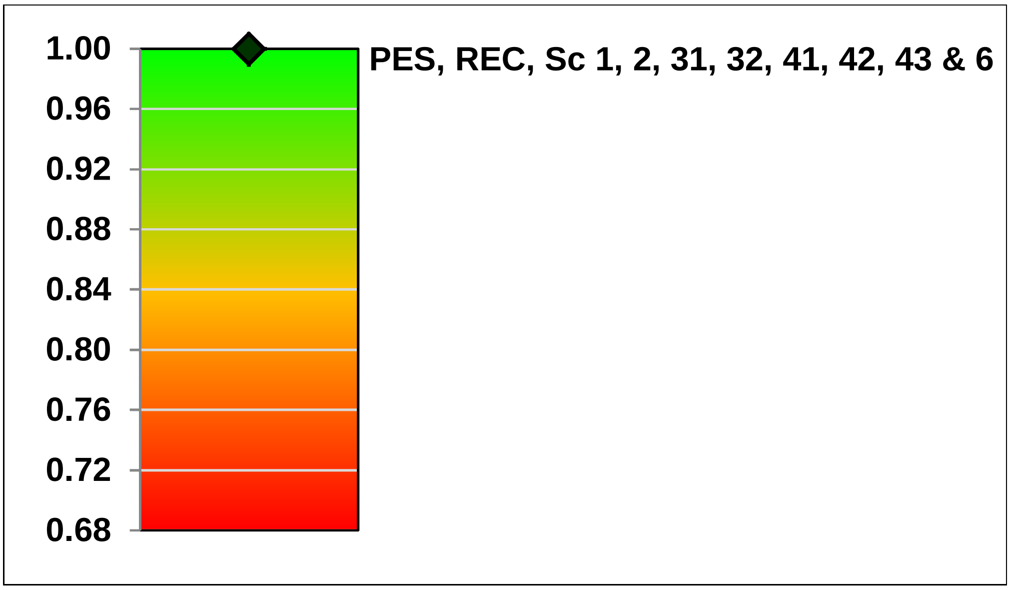

Figure 12.1 Ecological ranking of operational scenarios at KOMATI EWR K3

13 KOMATI CATCHMENT (X1) - ECOLOGICAL CONSEQUENCES AT EWR L1 (KLEINDORINGKOP): LOMATI RIVER

The current flow exceeds natural during the dry season due to the releases from Driekoppies Dam. The seasonal variability has therefore always been the major impacts on the ecosystem. The range of scenarios are very similar with Sc K42, K43, K32, K33 and K6 resulting in even higher flows than PD.

13.1 CHANGES IN FLOW REGIME

At Komati EWR L1 (on the Lomati River), the PD MAR is 239 Mm^3 and volume necessary to achieve the PES is 45 Mm^3. The MAR of Sc 32 is 229 Mm^3, representing a negligible change in volumes from the PD conditions. Under Sc 31 stream permanency remains at 100% (as does Natural, PD and the PES requirement).The MAR is 40% of the PD and 90% of the PES requirement. Flows exceed natural for a large proportion of the time from July to November, but are less than natural in the remaining months (most of the wet season). Seasonality is reversed (as is PD) with higher flows in the dry season and lower flows in the wet season (base flow). The wet season is similar to PD with reduced flows at times. Dry season flows are more than natural, PD and PES requirement.

The driver components are summarised in Table 13.1 and the response components in Table 13.2. Summaries are provided in Table 13.4 and Figure 13.1.

13.2 KLEINDORINGKOP EWR L1: ECOLOGICAL DRIVER COMPONENTS

Table 13.1 Kleindoringkop EWR L1: Consequences on the ECs of the driver components

Sc	EC	Consequences
Physico chemical: PES and REC B/C* (81.8%)		
32	B (87.4%)	Flows exceed PES for most of the year, with an improvement evident in salts, nutrients, temperature and oxygen.
Geomorphology: PES and REC (D) (45%)		
32	D (45%)	The low PES for geomorphology (D Category) of the 2006 EWR study is supported by the D Category of the river determined in the DWA PES-EIS assessments of 2011 for this (X14H-01066) sub-quaternary catchment. The low PES is due to catchment erosion, riparian vegetation removal but primarily flow stabilisation and loss of floods below a large dam. Under Sc K32, there will be some change to the low flow conditions, but these will not affect a change in the geomorphology and the site will remain in the PD (PES) condition of a D.

* Note that the PES of a B/C was taken from a PAI table prepared using the data in the water quality table for EWR L1 in DWAF (2006), i.e. the Water Quality Report for the Komati EWR study; pg. 46.

13.3 KLEINDORINGKOP EWR L1: ECOLOGICAL RESPONSE COMPONENTS

Table 13.2 Kleindoringkop EWR L1: Consequences of the ECs on the response components

Sc	EC	Consequences
Fish: PES and REC (C) (64.8%)		
32	C (64.8%)	In terms of both total flows and low (base) flows, and for both maintenance (70% flow duration) and drought flows (95% flow duration) there seems to be less stress on the fish assemblage during all wet and dry season months (when comparing to PES-EWR). Although flows will therefore be adequate and an improvement in water quality is expected, loss of marginal vegetation may affect some fish species with a preference for this habitat feature negatively, further aggravated by reversed seasonality of flows. Some species will therefore be favoured while other will be negatively impacted and hence it is estimated that the overall fish assemblage may remain in its current PES of a C.
Macro-invertebrates: PES and REC (C) (76.6%)		
32	C (68%)	Compared with the PES, most of the flows and the water quality have improved (stream permanency remains at 100%), and thus there will be less stress on the macro-invertebrate communities. Adverse conditions impacting on the marginal vegetation include inundation stress in the dry season which is likely to clear vegetation form the marginal and lower zones, impacting on macro-invertebrate assemblages associated with these zones. Therefore, the combination of improved flow and water quality conditions, and the adverse impact on the marginal vegetation component, results in a slightly lower C Category.
Riparian vegetation: PES and REC (B/C) (79%)		
32	C/D (57.9%)	Inundation stress in the dry season is likely to clear vegetation form the marginal and lower zones, with marked loss of riparian habitats in these zones. Also likely to intensify zonation of the upper zone and promote woody cover.

13.4 KLEINDORINGKOP EWR L1: ECOSTATUS

The resulting ECs for each component and EcoStatus is provided in Table 13.3. The ranking of the scenarios are provided on a traffic diagram (Figure 13.1). The results illustrate that Sc K2, K31 and K41 are similar to the PES whereas the other scenarios are in a worse state due to the impacts on riparian vegetation which in turn impacts the instream components. This results in a C/D EcoStatus.

Table 13.3 Ecological consequences at KLEINDORINGKOP EWR L1

Component	PES	REC	Sc K1	Sc K2	Sc K6	Sc K31	Sc K32	Sc K41	Sc K42	Sc K43
Physico chemical	B/C	B/C	B/C	B/C	B	B/C	B	B/C	B	B
Geomorphology	D	D	D	D	D	D	D	D	D	D
Fish	C	C	C	C	C	C	C	C	C	C
Invertebrates	C	C	C	C	C	C	C	C	C	C
Riparian vegetation	B/C	B/C	B/C	B/C	C/D	B/C	C/D	B/C	C/D	C/D
EcoStatus	C	C	C	C	C/D	C	C/D	C	C/D	C/D

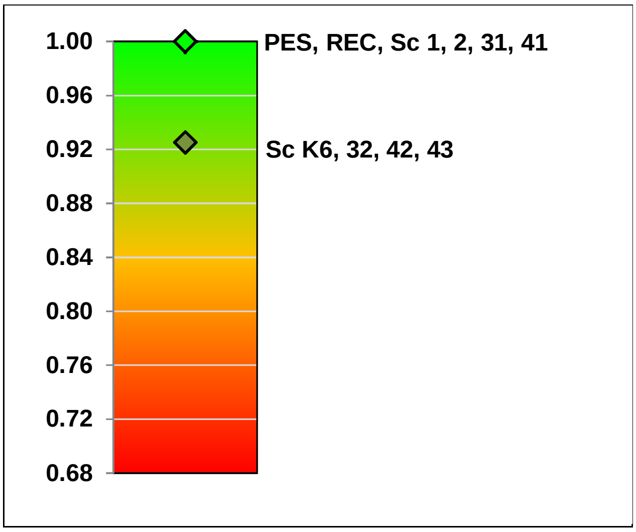

Figure 13.1 Ecological ranking of operational scenarios at KLEINDORINGKOP EWR L1

14 CONCLUSIONS

14.1 SCENARIO ECOLOGICAL CONSEQUENCES: SABIE RIVER SYSTEM

The scenarios only impact on EWR S3 (Sabie River) and EWR S5 (Marite River). At all the other EWR sites, the status quo is therefore maintained.

The ranking of the scenarios at each site in terms of how successful the scenarios are in meeting the REC is provided in Figure 14.1. The ranking order is quite different between EWR S3 and EWR S5 due to the operation of the system. Inyaka Dam is situated in the Marite River upstream of EWR S5. Operation of the Sabie River is dependant on releases from Inyaka Dam, whether it is for the EWR and/or the users. In essence, as is currently the case, the impacts of this operating rule on the Marite River result in releases that do not mimic the natural seasonal distribution and often results in too much flows (i.e. flows higher than natural). None of the scenarios therefore achieve the REC in the Marite River which would require smaller releases at times. Scenario S31 is marginally better than the PES whereas Sc S1 and S32 result in an EcoStatus below the PES. The ranking shows that Sc S1 and S32 are the lowest in the ranking and significantly lower than the other scenarios.

The ranking in the Sabie River follows a similar order to the Marite River except for Sc S6 which is at opposite ends of the ranking. Scenario S6 was designed as an optimised scenario to ensure that the EWR is met in the Sabie River. To meet the EWR, additional releases from Inyaka Dam is required and that is why Sc S6 results in ecological degradation in the Marite River. Scenario S32 is the worst scenario in the Sabie River as well as in the Marite River.

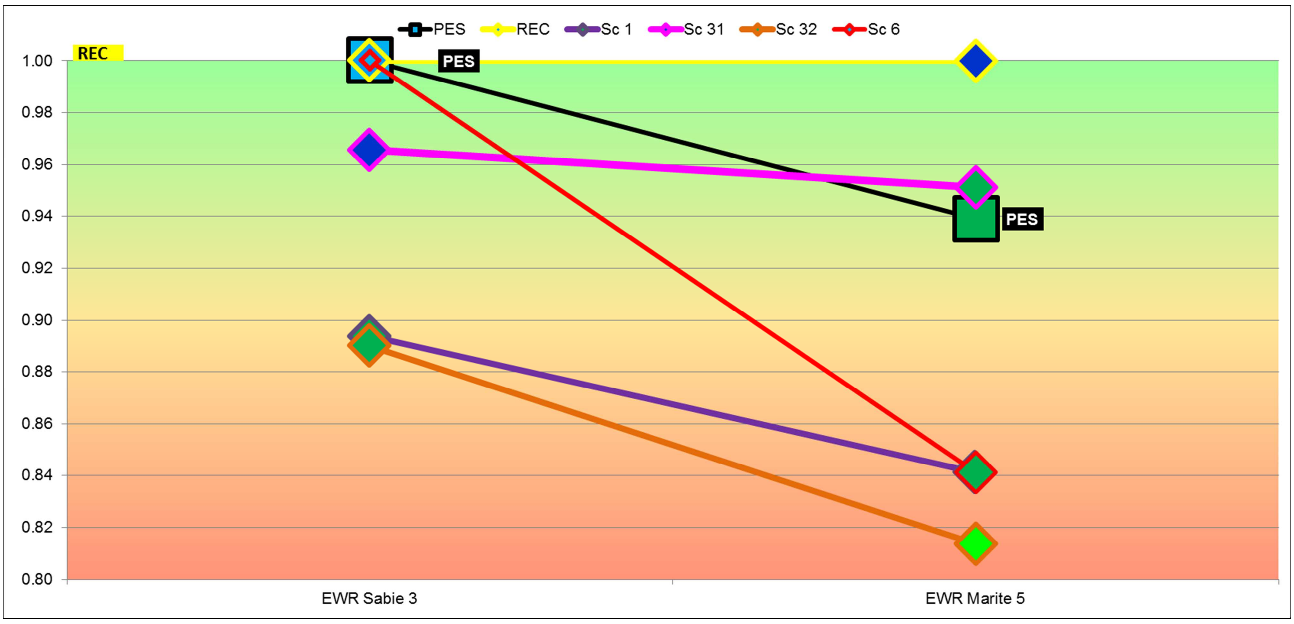

Figure 14.1 Sabie River: Ranking of scenarios at EWR S3 and EWR S5

The process to determine an integrated ranking of the different scenarios is described below. The first step was to determine the relative importance of the different EWR sites. The site weight (Table 14.1) indicates that EWR S3 carries the highest weight due to its high ecological importance and as it represents the KNP.

The weights are provided in the Table 14.1. The weight is based on the conversion of the PES and EIS to numerical values to determine the normalised weight.

Table 14.1 Sabie River system: Weights allocated to EWR sites relative to each other

EWR site	PES	EIS	Locality in protected areas (0 - 5)	Confidence	Normalised Weight
EWR S1	B/C	High	1	3.25	0.17
EWR S2	C	High	2	3.25	0.19
EWR S3	A/B	Very High	5	3.75	0.26
EWR S4	B	High	3	3.15	0.21
EWR S5	B/C	High	1	3.25	0.17

The weight is applied to the ranking value for each scenario at each EWR site and this provides an integrated score and ranking for the operational scenarios of the Sabie River system. The ranking of '1' refers to the REC and the rest of the ranking illustrate the degree to which the scenarios meet the REC. The results are provided in Table 14.2 after the weights have been taken into account. Values for EWR S3 and S5 only have been provided as the scenarios do not impact on the other EWR sites.

Table 14.2 Sabie River system: Ranking value for each scenario resulting in an integrated score and ranking

EWR	PES	REC	Sc S1	Sc S31	Sc S32	Sc S6
EWR S3	0.26	0.26	0.24	0.26	0.24	0.26
EWR S5	0.16	0.17	0.15	0.17	0.14	0.15
Score	**0.97**	**1**	**0.92**	**0.96**	**0.92**	**0.95**

The above results are plotted on a traffic diagram (Figure 14.2) to illustrate the integrated ecological ranking.

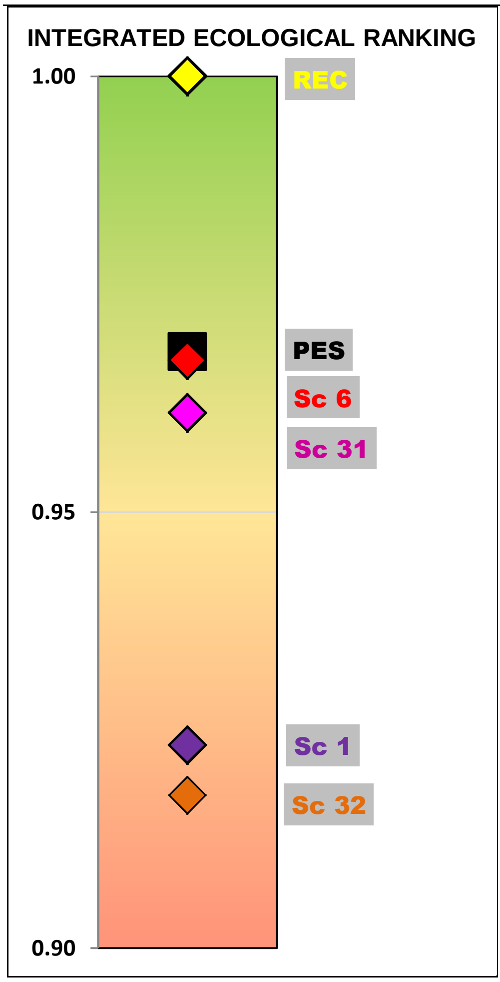

Figure 14.2 Sabie River system: Integrated ecological ranking of the scenarios

Scenario S31 and S6 are the best options as they are the closest to meeting the ecological objectives. If one however considers that the Sabie River has always been seen as the flagship river in the KNP as well as one of the few rivers left in South Africa in excellent condition, then the ranking order of the Sabie River should (from an ecological view point) override the integrated ranking. As Sc S6 is the only scenario that maintains the PES (and REC) in the Sabie River, this scenario is the ecological recommendation.

14.2 SCENARIO ECOLOGICAL CONSEQUENCES: SAND RIVER SYSTEM

The scenarios largely impact on EWR S6 (Mutlumuvi River) and EWR S8 (Sand River). Due to the lower confidence at EWR S7 (Thulandziteka (Sand) River) and as it is situated upstream of the impact of the New Forest Dam, this site was not considered during the scenario evaluation.

The results at EWR S6 (Mutlumuvi River) illustrate that none of the scenarios meet the ecological objectives of the REC. Scenario S4 meets the ecological objectives of the PES and has the least impact of all the scenarios. Scenario S51 and S71 result in the PES EcoStatus although geomorphology and fish are impacted. Scenario S53 and S73 result in a deterioration in the PES while Sc S52 and S72 have serious impacts as the EWR site will receive zero flows except when the dam spills.

Although affected by the proposed New Forest Dam under Sc S51, S52 and S53, the impacts of these scenarios are ameliorated by the return flows from the lower catchment. Scenario S72 is marginally lower than the EWR during some months but does maintain the REC for all components and the EcoStatus.

The ranking order is the same for both sites with Sc S72 being the worst case at both sites (Figure 14.3).

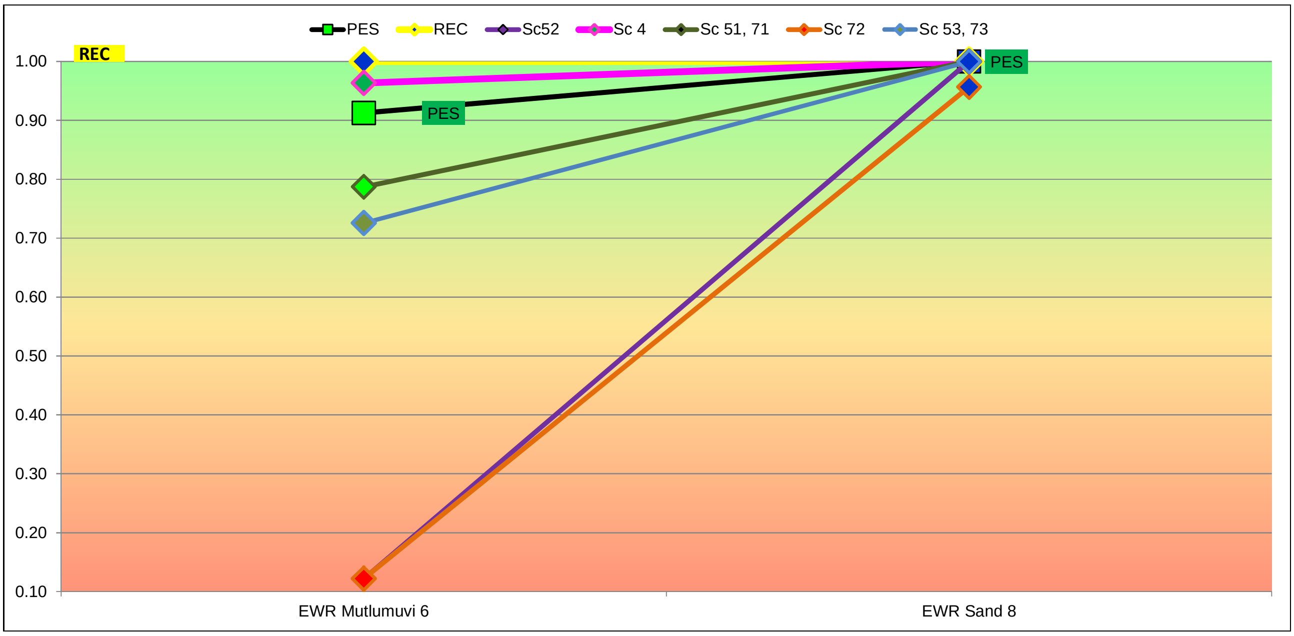

Figure 14.3 Sand River system: Ranking of scenarios at EWR S6 and EWR S8

The process to determine an integrated ranking of the different scenarios is described below. The first step was to determine the relative importance of the different EWR sites. The site weight (Table 14.3) indicates that EWR s8 carries the highest weight due to its high ecological importance and as it represents the KNP.

The weights are provided in the Table 14.3. The weight is based on the conversion of the PES and EIS to numerical values to determine the normalised weight.

Table 14.3 Sand River system: Weights allocated to EWR sites relative to each other

EWR site	PES	EIS	Locality in protected areas (0 - 5)	Confidence	Normalised Weight
EWR S6	C	High	1	3.25	0.43
EWR S8	B	High	5	2.5	0.57

The weight is applied to the ranking value for each scenario at each EWR site and this provides an integrated score and ranking for the operational scenarios of the Sand River system. The ranking of '1' refers to the REC and the rest of the ranking illustrate the degree to which the scenarios meet the REC. The results are provided in Table 14.4 after the weights have been taken into account.

Table 14.4 Sand River system: Ranking value for each scenario resulting in an integrated score and ranking

EWR	PES	REC	Sc 4	Sc 51	Sc 52	Sc 53	Sc 71	Sc 72	Sc 73
EWR 6	0.40	0.43	0.42	0.34	0.05	0.32	0.34	0.05	0.32
EWR 8	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.54	0.57
Score	**0.96**	**1**	**0.98**	**0.91**	**0.62**	**0.88**	**0.91**	**0.59**	**0.88**

The above results are plotted on a traffic diagram (Figure 14.4) to illustrate the integrated ecological ranking.

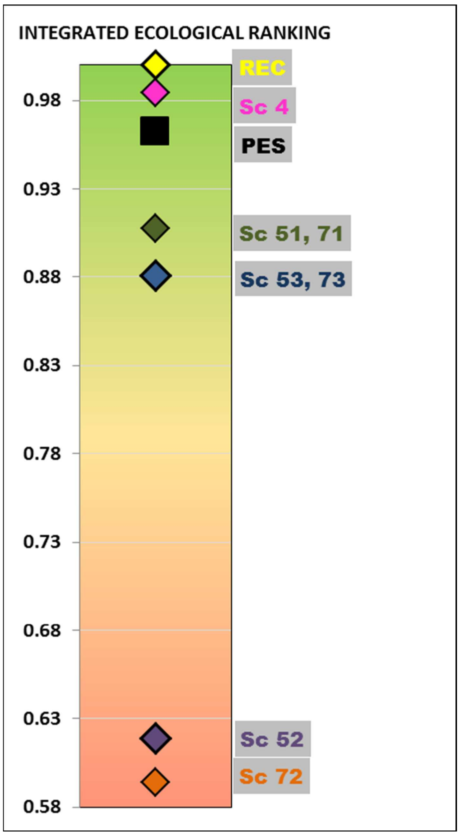

Figure 14.4 Sand River system: Integrated ecological ranking of the scenarios

Scenario S52 and S72 are not viable options as a section of the Mutlumuvi River will change to a seasonal system. Scenario S4, although the best option, was recognised not to be a realistic option as the return flows associated with this scenario are too high. Scenario S51 and S53 also include these return flows. The remaining scenarios are Sc S71 and S73. Scenario S71 includes a full EWR release which will have a major impact on the yield. To further optimise, it is recommended that Sc S73 be further investigated.

14.3 SCENARIO ECOLOGICAL CONSEQUENCES: CROCODILE RIVER SYSTEM

The scenarios only impact on EWR C3, C4, C5 and C6 in the Crocodile River and on EWR K7 in the Kaap River.

EWR C3: The results illustrate that none of the scenarios meet the ecological objectives of the REC. Only Sc C61 maintains the EcoStatus PES although there is deterioration in geomorphology. The major issue is that EWR C3 is downstream of Kwena Dam and that current and scenario releases are unseasonal resulting in too high flows in winter and too little flows in summer.

EWR C4: The results illustrate that all the scenarios meet the ecological objectives of the PES and of these scenarios Sc C62 and C72 result in an improvement in the PES, although the REC requirements are not met. This site is upstream of the major off-takes into canals for irrigation further downstream and the problems (current and with scenarios) are the constraints on the operation for irrigation resulting in an unseasonal distribution of flows.

EWR C5: The results illustrate that all the scenarios meet the ecological objectives of the PES and of these scenarios Sc C2, C4. C61, C71, C81 and C82 result in an improvement in the PES, although the REC requirements are not met.

EWR C6: This site is the key site in the system, both from an operational and ecological importance viewpoint. The results illustrate that Sc C5 and Sc C72 do not meet the ecological objectives of the PES or the REC and are the worst case scenarios. ScenarioC4, C61, C71 and Sc C81 meet the REC requirements. Scenario C2 also meets the REC requirements although the ecological objectives for macro-invertebrates are not fully met. Scenario C1, C3, C62 and Sc C82 meet the PES requirements however the instream biota are impacted to a greater extent under these scenarios and ecological objectives are not fully met for fish and macro-invertebrates. Scenario C1 is the worst scenario in this group for the fish, macro-invertebrate and riparian vegetation components. This will mean that if Sc C1 is implemented, there is a high risk that the EcoStatus will drop to a lower category.

EWR K7: The results illustrate that Sc C72 does not meet the ecological objectives of the PES or the REC. The rest of the scenarios meet the PES EcoStatus requirements although there is deterioration in macro-invertebrates. Of these scenarios, Sc C2 and C4 are the best scenarios as there is a small improvement in the PES.

The individual site rankings are illustrated in Figure 14.5.

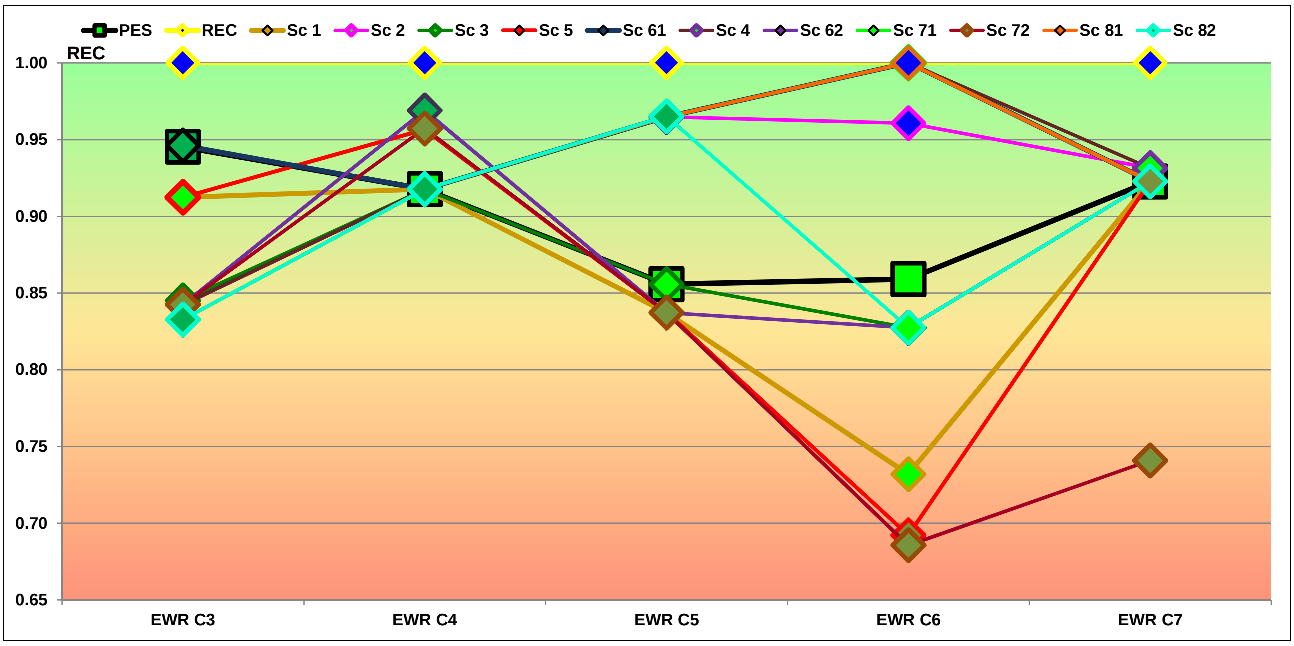

Figure 14.5 Crocodile River system: Ranking of scenarios

The process to determine an integrated ranking of the different scenarios is described below. The first step was to determine the relative importance of the different EWR sites. The site weight (Table 14.5) indicates that EWR C6 carries the highest weight due to its high ecological importance and as it represents the KNP. Furthermore it is situated at the most downstream reach of the Crocodile River system and therefore plays an important role in monitoring.

The weights are provided in the Table 14.5. The weight is based on the conversion of the PES and EIS to numerical values to determine the normalised weight.

Table 14.5 Crocodile River system: Weights allocated to EWR sites relative to each other

EWR site	PES	EIS	Locality in protected areas (0 - 5)	Confidence	Normalised Weight
EWR C1	A/B	Moderate	1	3.75	0.13
EWR C2	B	High	1	3.5	0.13
EWR C3	B/C	High	1	2.5	0.11
EWR C4	C	High	2	2.5	0.13
EWR C5	C	Very High	5	3.4	0.18
EWR C6	C	Very High	5	4	0.20
EWR K7	C	High	1	2.75	0.12

The weight is applied to the ranking value for each scenario at each EWR site and this provides an integrated score and ranking for the operational scenarios of the Crocodile River system. The ranking of '1' refers to the REC and the rest of the ranking illustrate the degree to which the scenarios meet the REC. The results are provided in Table 14.6 after the weights have been taken into account.

Table 14.6 Crocodile River system: Ranking value for each scenario resulting in an integrated score and ranking

EWR site	PES	REC	Sc C1	Sc C2	Sc C3	Sc C4	Sc C5	Sc C61	Sc C62	Sc C71	Sc C72	Sc C81	Sc C82
EWR C1	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
EWR C2	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
EWR C3	0.11	0.12	0.11	0.10	0.10	0.10	0.11	0.11	0.10	0.10	0.10	0.10	0.10
EWR C4	0.12	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
EWR C5	0.16	0.18	0.15	0.18	0.16	0.18	0.15	0.18	0.15	0.18	0.15	0.18	0.18
EWR C6	0.17	0.20	0.15	0.19	0.17	0.20	0.14	0.20	0.17	0.20	0.14	0.20	0.17
EWR K7	0.09	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.07	0.09	0.09
Score	**0.92**	**1**	**0.89**	**0.95**	**0.903**	**0.96**	**0.89**	**0.97**	**0.91**	**0.96**	**0.86**	**0.96**	**0.92**

The above results are plotted on a traffic diagram (Figure 14.6) to illustrate the integrated ecological ranking.

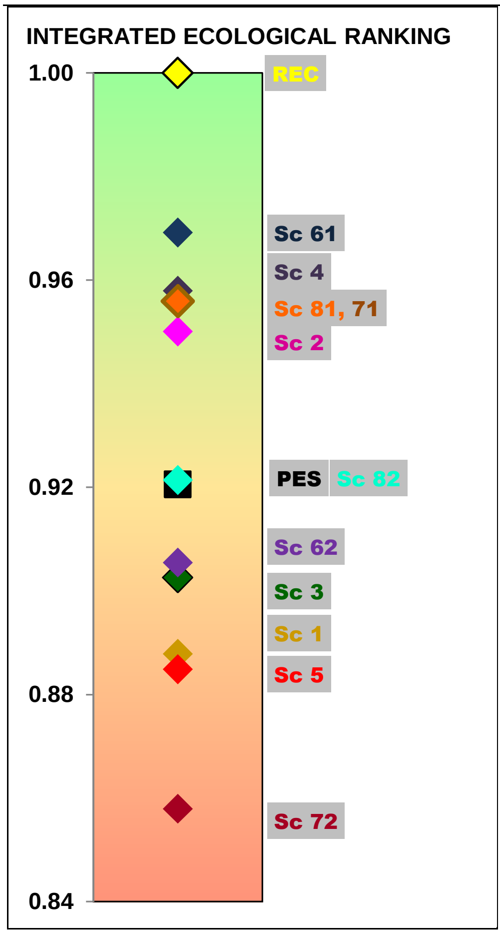

Figure 14.6 Crocodile River system: Integrated ecological ranking of the scenarios

The worst case scenarios are Sc C72 and C5 which both include new dam options but with no EWR releases. Scenario C1 which represents the current operating rule also has the potential to degrade the river although it will still maintain the EcoStatus of a C at EWR C6. The best options are those options that include the REC. It is however known that these have serious potential economic consequences. Scenario C3 (with no new dams) and Scenario C82 (that includes new dams) are potentially the best compromise options to explore further.

14.4 SCENARIO ECOLOGICAL CONSEQUENCES: KOMATI SYSTEM

The scenarios are described in Table 6.1. The scenarios applicable to the Komati River system only impact on EWR K3 (Komati River at Tonga Rapids) and EWR L1 (Lomati River downstream of Driekoppies Dam).

Recent changes in the lower Komati operating rule from Maguga Dam have resulted in improvement in the system since the 2004 – 2006 EWR study (AfriDev, 2006a). The results illustrate that all the scenarios meet the ecological objectives at EWR K3.

The Lomati River at EWR L1 is largely impacted on by the unseasonal releases for irrigation from Driekoppies Dam. The scenario results illustrate that Sc K2, K31 and K41 are similar to the present day flows (i.e. maintain the PES) whereas the other scenarios are in a worse state due to the impacts on riparian vegetation which in turn impacts on the instream components. This results in a change from a C to a C/D EcoStatus.

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16 APPENDIX A: STRESS INDICES FOR THE EWR SITES LOCATED IN THE SABIE, SAND AND CROCODILE CATCHMENTS

The stress indices generated during the 2009 Comprehensive Reserve (DWA, 2010a;b) is provided in Section 16.1 and 16.2 for the Sabie-Sand and Crocodile catchment respectively. These stress indices serves as additional interpretive information on the ecological consequences of the response components discussed in the main section of this document.

16.1 SABIE-SAND RIVER SYSTEM

16.1.1 EWR S3: Kidney (Sabie River)

Table 16.1 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
0 (SR)	16.55	Fish guild habitats are at an optimum (5*). FDI[1] Habitat is heterogeneous and plentiful. Lower limit of *B. salicina* inundated. No water stress. Riparian vegetation: Adults with full vigour and at maximum reproductive capacity.
1 (SR)	13.74	LSR[2] habitat is at optimum with spawning habitat slightly reduced. SR[3] habitat is slightly reduced (4.5)* but water quality and connectivity is optimal. FDI as above. Taxa abundant and healthy.
2 (SR)	10.33	SR habitat is good while connectivity and water quality along with LSR habitat is slightly better. Critical habitats sufficient. Indicator taxa persist.
3 (FDI)	8.78	SR habitat is slightly higher than moderate while connectivity and water quality is good. LSR habitat is good. Critical FDI habitat reduced with moderate quality. Most indicator taxa persist at reduced abundances. Riparian vegetation: Adults with full vigour and at maximum reproductive capacity.
4 (FDI)	6.65	Critical FDI habitat limited. Life stages of indicator taxa viable.
5 (FDI)	4.78	SR guild: Connectivity and water quality is moderate while rest of habitats are slightly worse (2.5). LSR guild: Nursery and connectivity is higher than low (2.5), spawning habitat is low and abundance and cover is moderate. Critical FDI habitat very reduced. Perlidae decline in abundance and occupy remaining fast flowing areas. Heptageniidae and Elmidae persist at low abundances. *P. mauritianus*: Leaf wilting/stress commences, but is slight.
6 (FDI)	2.25	SR guild: Spawning and nursery habitat is low (1.5 – 2), connectivity is moderate. LSR habitat is low while spawning areas are very low in occurrence. Critical habitat residual and of low quality. Perlidae rare, critical stages of sensitive indicator taxa non-viable, and at risk for less sensitive Heptageniidae and Elmidae. *B salicina*: Leaf wilting/stress commences, but is slight.
7 (SR)	1.84	SR and LSR habitat is very low with some connectivity.
8 (SR)	1.46	SR and LSR habitat is as above although slightly deteriorated. LSR spawning habitat has nearly disappeared. Heptageniidae and Elmidae persist, but Perlids all but disappear, with all life-stages of sensitive indicator taxa at risk or non-viable. *P. mauritianus*: Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed).
9 (SR)	1.13	SR guild: All habitats are very low and rare. LSR guild: Habitat is very low and spawning habitat is very rare.
10	0	Only pool dwelling species present. Standing water habitats only, very poor quality. Indicator taxa disappear. Widespread and complete mortality of riparian population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

1 Flow dependant (FDI) cobble dwelling macroinvertebrates

2 Large semi-rheophilic fish species

16.1.2 EWR S5: Marite (Marite River)

Table 16.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
0 (Reeds)	4.9	Fish guild habitats are at an optimum (5*). All FDI habitat in excess. Taxa abundant. *Phragmites*adults with full vigour and at maximum reproductive capacity.
1 (Reeds)	3.647	Fish habitats are slightly less (4.5)* with nursery, connectivity and water quality still at an optimal. FDI habitat plentiful. *Breonadia* adults with full vigour and at maximum reproductive capacity.
2 (FDI)	2.7	Fish habitats are good (4) with nursery, connectivity and water quality still at an optimal. All FDI indicator taxa present, but the Perlidae and Heptageniidae are less abundant.
3 (LR)	1.78	Fish spawning, abundance and cover habitat is moderate while rest of habitat is good – optimal. Critical FDI habitat reduced with moderate quality. Most indicator taxa persist at reduced abundances. Leaf wilting/stress commences, but is slight.
4 (LR)	1.375	Fish spawning habitat for both guilds have deteriorated (2.5). Abundance and cover for the SR guild is low (2.5) and moderate (3) for the LR guild while the rest of the habitats for both guilds. Reduced FDI critical habitat and quality. *Phragmites*: Leaf wilting/stress commences, but is slight.
5 (LR)	0.97	Nursery habitat for both guilds is moderate, while the rest of the habitats are low (2). Connectivity for the SR guild is good (4) and moderate – good (3.5) for the LR guild. All life stages of Perlidae, Elmidae and Heptageniidae are viable in limited areas, critical life stages of some sensitive rheophilic species at risk.
6 (LR)	0.69	Nursery habitat is the same as above but the rest of the habitat occurrences have deteriorated (1.5) Critical FDI habitat limited. Critical life-stages of sensitive indicator taxa at risk or non-viable.
7 (LR)	0.5	Fish habitat as above albeit slightly reduced. LS spawning habitat is rare (0.5).
8 (LR)	0.35	LR spawning habitat is absent, while cover and abundance is very rare (0.5). SR spawning habitat is rare while rest of habitat is very low. Elmidae and Heptageniidae persist but at very low numbers. All life stages of most rheophilic taxa at risk or non-viable. Riparian vegetation: Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed).
9 (LR)	0.29	Fish habitat as above with a reduction in water quality and connectivity. Critical FDI habitat residual and of low quality. Elmidae and Heptageniidae persist but at very low numbers. All life stages of most rheophilic taxa at risk or non-viable.
10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water. Widespread and complete mortality of population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

16.1.3 EWR S6: Mutlumuvi (Mutlumuvi River)

Table 16.3 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
0 (Minger)	1.6	Fish guild habitats are at an optimum (5*). All FDI habitat in excess. Taxa abundant. *Phragmites*adults with full vigour and at maximum reproductive capacity.
1 (Minger)	1.25	Fish guilds as above. FDI taxa as above.
2 (Minger)	0.93	Fish as above. Critical FDI habitat sufficient. All indicator taxa present, but Hydropsychidae and Heptageniidae are less abundant.
3 (FDI)	0.83	Fish habitat is good with optimal water quality. Reduced FDI critical habitat and quality. Leaf wilting/stress commences, but is slight. All indicator taxa present, but Heptageniidae and Hydropsychidae are much less abundant.
4	0.78	All life stages of Heptageniidae and Hydropsychidae are viable in limited areas, critical life stages

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
(FDI)		of some sensitive rheophilic species at risk.
5 (FDI)	0.73	SR guild: Moderate habitat with good connectivity and water quality. LSR guild spawning habitat is low (2.5) with other habitats good. Critical FDI habitat limited. Critical life-stages of sensitive indicator taxa at risk or non-viable.
6 (FDI)	0.64	SR guild: Low (2.5) habitat with moderate connectivity and good water quality. LSR guild: Low spawning habitat with good nursery habitat and water quality and other habitat occurrences moderate. Critical habitat very reduced. Heptageniidae and Hydropsychidae occur in very low numbers, critical stages of sensitive rheophilic species non-viable, and at risk for some less sensitive species.
7 (SR)	0.46	SR guild: Spawning habitat rare (0.5), other habitat very low and moderate connectivity and water quality. LSR guild: Spawning habitat is rare, while nursery habitat and water quality is moderate and the rest of the habitat very low (1.5). Critical FDI habitat residual. *Breonadi*a: Leaf wilting/stress commences, but is slight.
8 (SR)	0.38	Spawning habitat for both guilds is absent. LSR habitat is low (2.5) while nursery habitat is rare for SR guild and other habitats are low – very low (1 – 2). Critical FDI habitat absent. Heptageniidae and Hydropsychidae persist but at very low numbers. All life stages of most rheophilic taxa at risk or non-viable. Riparian vegetation: Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed).
9 (SR)	0.163	SR spawning and nursery habitat absent while rest of habitat is very low. LSR spawning habitat is absent and rest of habitat is very low. *Breonadia*: Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed).
10	0	Spawning habitat is absent while other habitat is very rare (0.5). Standing water only. Indicator taxa no longer present. Inverts: Widespread and complete mortality of population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

16.2 CROCODILE RIVER SYSTEM

16.2.1 EWR C3: Polar Creek (Crocodile River)

Table 16.4 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
0 (SR)	7.3	SR guild: All habitat is optimal (5*). All habitats in excess. All FDI indicator taxa very abundant and healthy.
1 (SR)	5.17	SR guild: All habitats still optimal although abundance and cover is slightly impacted (4.5). All plentiful, high quality. 90% FDI indicator taxa persist.
2 (SR)	3.08	SR guild: Spawning, connectivity and water quality is very high (4 – 4.5) while abundance and cover is moderate (3 – 3.5).
3 (SR)	2.73	SR guild: Moderate (3) spawning and cover occurs with low (2.5) abundance and good water quality and connectivity. *S. mucronata* and *Cliffortia*: Adults with full vigour and at maximum reproductive capacity. 50% *Salix* population inundated, upper limit rooting depth at 15 to 25 cm. Cliffortia upper limit at 75 cm rooting depth.
4 (SR)	2.155	SR guild: Similar to above although connectivity is moderate (3.5) and cover is low (2.5). Critical habitats sufficient. Most FDI indicator taxa persist, but slight (80%) reduction.
5 (SR)	1.58	SR guild: Most habitat occurs in moderation although abundance is very low (1.5) and cover is low (2). Reduced critical habitat. All life stages viable in limited areas, critical life stages of some sensitive FDI indicator taxa at risk.
6 (SR)	1.13	SR guild: Abundance and cover is very low while water quality is moderate and the rest of the habitat is low. Critical habitats limited. Critical FDI life-stages of sensitive indicator taxa at risk or non-viable.
7 (SR)	0.945	Critical habitat very reduced. Sensitive FDI indicator taxa rare, critical stages of sensitive indicator taxa non-viable and at risk for some less sensitive taxa.
8 (SR)	0.76	*S. mucronata* and *Cliffortia*: Leaf wilting/stress commences, but is slight. *Salix*: 30 to 40 cm rooting depth for upper limit, lower limit at water level on average. *Cliffortia*: Up to 90 cm rooting

Integrated stress	Flow m³/s	Habitat and/or Biotic responses
		depth.
9 (SR)	0.361	All habitat very scarce and nearly absent (0.5). Critical habitat residual. Some FDI indicator taxa persist, but most disappear. All life-stages of sensitive indicator taxa at risk or non-viable.
10 (SR)	0	Only hyporheic refugia, no surface water. FDI Indicator taxa no longer present. *S. mucronata* and *Cliffortia*: Widespread and complete mortality of population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

16.2.2 EWR C4: Kanyamazane (Crocodile River)

Table 16.5 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m³/s	Habitat and/or Biotic responses
0 (SR)	18.6	All habitat is optimal (5*) for the SR and LSR guild although abundance and connectivity for the LSR guild is slightly less than optimal (4.5). FDI habitat is plentiful and of high quality. Indicator taxa abundant and healthy. *L. octovalvis* with full vigour and at maximum reproductive capacity. 50% population inundated, upper limit rooting depth at 14 cm.
1 (*Ludwigia*)	14.1	Fish guild as above. Critical FDI habitat is sufficient. 90% of indicator taxa persist. Riparian vegetation as above.
2 (*Ludwigia*)	11.6	All indicators as above.
3 (*Ludwigia*)	5.5	SR and LSR guild: Water quality is still optimal (5) while the rest of the habitat ids good (4 - 4.5). *L. octovalvis*: Leaf wilting/stress commences, but is slight. Up to 30 cm rooting depth for upper limit, lower limit at is at water level on average.
4 (*Ludwigia*)	4.7	SR and LSR guild: Water quality optimal with rest of habitats rated as good (4).
5 (*Ludwigia*)	3.5	SR guild: Most habitats are good (4), but abundance is moderate (3.5). LSR guild: Water quality and connectivity is good while spawning, abundance and cover is moderate (3.5). Reduced critical habitat. Most indicator taxa persist, but slight (80%) reduction. *L octovalvis*: Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread. 30 to 60 cm rooting depth for sufficient soil moisture, no inundation
6 (SR)	1.75	SR guild: Water quality and spawning habitat is moderate rest of habitat occurrence is low (2 - 2.5). LSR guild: All habitat occurrence is low (2 - 2.5).
7 (LSR)	1.2	*L. octovalvis*: Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). 30 – 90 cm rooting depth for sufficient soil moisture, mortality may occur for lower zone individuals.
8 (LSR)	0.8	*L. octovalvis*: Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable. 75 cm to 1 m rooting depth, individuals at upper limit likely to begin dying.
9 (LSR)	0.4	SR and LSR guild: All habitat occurrences are low. Critical FDI habitat very reduced. All life stages viable in limited areas, critical life stages of some sensitive indicator taxa at risk. *L. octovalvis*: Complete mortality of small proportion of the population.
10	0.001	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDI. Indicator taxa no longer present. Widespread and complete mortality of population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

16.2.3 EWR C5: Malelane (Crocodile River)

Table 16.6 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m³/s	Habitat and/or Biotic responses
0 (SR)	35	All Fish SR and LSR habitats are optimal (5*). All FDI and MVI habitat in habitat in excess. All indicator taxa very abundant and healthy. Riparian vegetation indicators with full vigour and at maximum reproductive capacity.

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
1 (MVI)	31	Fish guilds as above. FDI and MVI habitat plentiful. 90% of MVI indicator taxa persist, FDI indicator taxa as above. Riparian vegetation as above.
2 (MVI)	27.25	SR and LSR guild: Most habitats optimal with abundance and connectivity slightly less (4.5). Most MVI indicator taxa persist, but slight (80%) reduction. Riparian vegetation as above.
3 (MVI)	23.5	Critical FDI and MVI habitats sufficient. Most MVI indicator taxa persist, but abundances reduced, FDI indicator taxa as above. Riparian vegetation as above.
4 (MVI)	22	Reduced critical habitat and critical quality for both FDI and MVI taxa. All life stages of MVI taxa viable in limited areas, critical life stages of some sensitive indicator taxa at risk. FDI as above.
5 (MVI)	16	Critical FDI and MVI habitats limited and of moderate quality. Critical life-stages of sensitive MVI indicator taxa at risk or non-viable.
6 (MVI)	8	Critical FDI and MVI habitat residual. Sensitive MVI indicator taxa rare, critical stages of sensitive indicator taxa non-viable and at risk for some less sensitive taxa. 90% of FDI indicator taxa persist. Riparian vegetation: Adults with full vigour and at maximum reproductive capacity. 50% population inundated, upper limit rooting depth at 14 cm.
7 (MVI)	4.7	Critical FDI and MVI habitat residual and of low quality. Some MVI indicator taxa persist, but most disappear. All life-stages of sensitive indicator taxa at risk or non-viable. Most FDI indicator taxa persist, but slight (80%) reduction.
8 (SR)	3.5	Abundance (SR and LSR) and cover (LSR) very rare (0.5) while rest of habitat occurrences is very low (1). Riparian vegetation: Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread. 10 to 30 cm rooting depth for sufficient soil moisture, no inundation.
9 (SR)	2.1	SR guild: Abundance and cover absent while rest of habitats are very rare. LSR guild: Spawning and connectivity is absent; other habitats are very rare. Flowing FDI and MVI water habitats residual and of low quality. Some MVI indicator taxa persist, but at very low numbers. All life stages of most indicator taxa at risk or non-viable. Most FDI indicator taxa persist, but abundances reduced.
10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDI. Indicator taxa no longer present. Widespread and complete mortality of population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

16.2.4 EWR C6: Nkongoma (Crocodile River)

Table 16.7 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
0 (SR)	22.8	All Fish SR and LSR habitats are optimal (5*) although connectivity for the LSR guild is slightly impacted (4.5). Critical FDI habitats sufficient. All indicator taxa very abundant and healthy.
1 (LSR)	18.9	Fish guild: As above.
2 (LSR)	15.5	SR guild: Abundance and water quality is optimal while rest of habitats is slightly less than optimal (4.5). LSR guild: Water quality is optimal and spawning, nursery and abundance is very good (4). Cover and connectivity is moderate (3.5).
3 (LSR)	12.35	Reduced FDI critical habitat with reduced critical quality. Most indicator taxa persist, but slight (80%) reduction.
4 (LSR)	9.7	All fish habitat is moderate (3 – 3.5), but cover and connectivity for the LSR guild is low (3.5)
5 (LSR)	8.475	Critical FDI habitats limited with moderate quality. Most indicator taxa persist, but abundances reduced.
6 (LSR)	7.25	All fish habitat is low and connectivity for the LSR guild is very low (1.5).
7 (LSR)	5.32	All fish habitats are low (1 – 1.5) although connectivity, water quality and cover is low (2) for the SR guild.
8 (LSR)	3.83	All fish habitat is very low (1) and connectivity and water quality for the LSR guild is very rare (0.5). Critical FDI habitat residual. Critical life-stages of sensitive indicator taxa at risk or non-viable.

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
		Adults with full vigour and at maximum reproductive capacity. 50% population inundated, upper limit rooting depth at 12 cm.
9 (LSR)	1.7	All fish habitat is very rare (0.5). No critical FDI habitat, other habitats moderate quality. Some indicator taxa persist, but most disappear. All life-stages of sensitive indicator taxa at risk or non-viable.
10	0	Flowing water habitats residual low quality. Indicator taxa no longer present. *C. marginatus:* Complete mortality of small proportion of the population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

16.2.5 EWR K7: Honeybird (Kaap River)

Table 16.8 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
0 (SR)	5.02	SR and LSR guild: All habitats are optimal (5*). All FDI habitats in excess and of high quality. Taxa abundant and healthy.
1 (SR)	2.56	SR guild: Cover and connectivity slightly less than optimal (4.5) with rest of habitats optimal. LSR guild: Cover and water quality slightly less than optimal (4.5) with rest of habitats optimal. All FDI habitats plentiful. Tax abundant and healthy.
2 (SR)	1.9	
3 (SR)	1.37	SR guild: Cover and connectivity is moderate (3 – 3.5) while other habitat occurrences are good (4). LSR guild: Water quality is good and other habitat occurrence is moderate (3 – 3.5). Reduced critical FDI habitat. All indicator taxa very abundant and healthy. *P mauritianus:* Adults with full vigour and at maximum reproductive capacity. 50% population inundated, upper limit rooting depth at 28 cm.
4 (SR)	0.8	SR guild: Connectivity is low (2.5) and all other habitat is moderate. LSR guild: Water quality is moderate and all other habitat is low. Critical FDI habitat limited. Most indicator taxa persist.
5 (LSR)	0.615	
6 (LSR)	0.43	SR and LSR guild: Water quality is moderate and all other habitat occurrence range between 2 – 2.5 (low).
8 (LSR)	0.201	Critical FDI habitat very reduced. Most indicator taxa persist, but abundances reduced. *P. mauritianus:* Leaf wilting/stress commences, but is slight. Up to 43 cm rooting depth for upper limit, lower limit is at water level on average.
9 (LSR)	0.086	SR guild: Connectivity is very rare (0.5) while other habitats are very low (1). LSR guild: All habitat occurrences are very rare. Critical FDI habitat residual. All life stages viable in limited areas, critical life stages of some sensitive indicator taxa at risk.
10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDI. Indicator taxa no longer present. Widespread and complete mortality of population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

17 APPENDIX B: REPORT COMMENTS

Page &/ or section	Report statement	Comments	Changes made?	Author comment
All comments – largely editorial – received from Ms M Sekoele during December 2014 has been addressed. As this document is a supporting document to Report 4.1 the report information has been changed based on the comments on Report 4.1.				