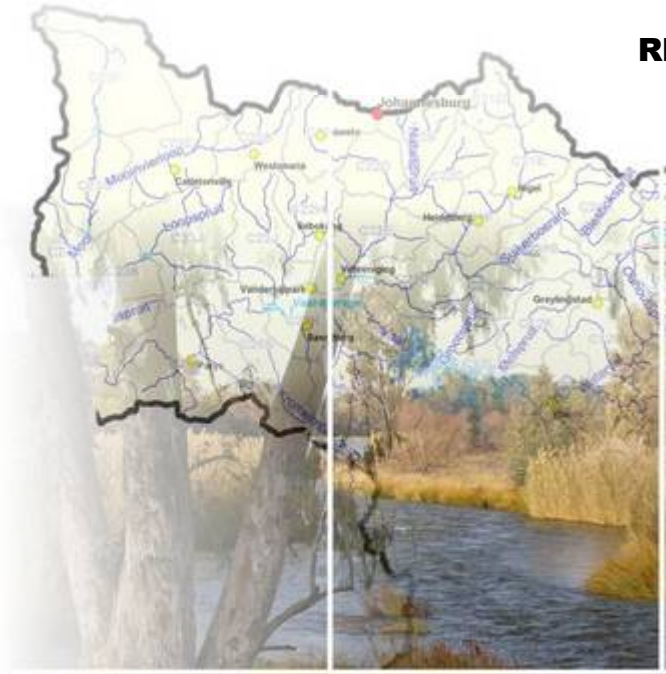
COMPREHENSIVE RESERVE DETERMINATION

INTEGRATED VAAL RIVER SYSTEM

SURFACE WATER

ECOSPECS REPORT

RDM/WMA8C000/01/CON/0310



TECHNICAL COMPONENT: UPPER VAAL

JULY 2010

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REPUBLIC OF SOUTH AFRICA

COMPREHENSIVE RESERVE DETERMINATION STUDY OF THE INTEGRATED VAAL RIVER SYSTEM

UPPER VAAL WATER MANAGEMENT AREA
TECHNICAL COMPONENT: ECOSPECS REPORT

Report number: RDM/WMA8C000/01/CON/0310

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Dr Kotze, Piet (Fish)
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EXECUTIVE SUMMARY

BACKGROUND

In order for the Department of Water Affairs (DWA) to make informed decisions regarding the authorization of future water use and the magnitude of the impacts of the present and proposed developments in the Vaal River System, higher levels of confidence is needed for the Reserve Determination within this study area. Therefore a Comprehensive Reserve determination study within Water Management Area (WMA) 8 has been undertaken to provide input to the Reconciliation studies and the integrated water quality management plan recently undertaken by the National Water Resources Planning Directorate (D: NWRP) of the DWA.

STUDY AREA

The Upper Vaal WMA is one of three WMAs in the Vaal River catchment, which is the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers (DWAF, 2004).

The major tributaries in the Upper Vaal WMA include the Vaal, Klip, Watervals, Wilge, Liebenbergsvlei, Suikerbosrand, Klipspruit and Mooi Rivers and extend to the confluence of the Mooi and Vaal Rivers. It covers a catchment area of 55 565 km^2. The locality of the Ecological Water Requirement (EWR) sites is provided in the table below. Information on site selection and the Management Resource Units (MRUs) are provided in DWAF (2008a) (Report RDM/WMA8C000/01/CON/0208).

EWR site number	EWR site name	River	National RHP site	Co-ordinates		EcoRegion (Level II)[2]	RU	Quat
				Latitude	Longitude			
EWR 1	Uitkoms	Vaal	C1Geel_Unspe	-26.8728	29.61384	11.05	MRU Vaal B	C11J
EWR 2	Grootdraai	Vaal	C1Vaal Braks	-26.9211	29.27929	11.03	MRU Vaal C	C11L
EWR 3	Gladdedrift	Vaal	C1Vaal-Villie	-26.99087	28.72971	11.03	MRU Vaal C	C12H
EWR 4	De Neys	Vaal	C2Vaal-Deny	-26.84262	28.1123	11.03	MRU Vaal D	C22F
EWR 5	Scandinavia	Vaal		-26.93243	27.01367	11.08	MRU Vaal E	C23L
EWR 6	Klip	Klip	C1Klip-Unspe2	-27.36166	29.48503	11.06	MRU Klip C	C13D
EWR 7	Upper Wilge	Wilge		-28.20185	29.55827	11.03	MRU Wilge A	C81A
EWR 8	Bavaria	Wilge	C8Wilg-Belwh	-27.80017	28.76778	11.03	MRU Wilge B	C82C
EWR 9	Suikerbos US	Suikerbosrand	C2Suik-Dehoe	-26.6467	28.38197	11.01	RU Suiker A	C21C
EWR 10	Suikerbos DS	Suikerbosrand	Close to C2Suik-Badfo	-26.68137	28.16798	11.01	RU Suiker B	C21G
EWR 11	Blesbokspruit	Blesbokspruit	C2Bles-Marai (locality incorrect)	-26.47892	28.42488	11.03	RU Bles A	C21F
RE-EWR 1	Klein Vaal	Klein Vaal	C1KVaal-unspe	-26.9128	30.17497	11.02	MRU Kvaal A	C11C
RE-EWR 2	Mooi	Mooi	Close to C2Mooi-Klerk	-26.2587	27.15973	11.01	RU Mooi B	C23G

PURPOSE OF THE REPORT

The purpose of this report is to present the Ecological Specifications (EcoSpecs) and Thresholds of Potential Concern (TPCs) for each of the EWR sites on the Upper Vaal River System. These EcoSpecs define the conditions that would occur under the Present Ecological State (PES). TPCs are provided to indicate worsening conditions. Where relevant, the conditions that describe the REC (when different than the PES) are also provided. This information forms the key inputs into an Ecological Water Resource Monitoring (EWRM) Program for these catchments. Further information on EcoSpecs and TPCs and their use in Ecological Water Resources Monitoring can be obtained from DWA (2009), and Kleynhans *et al*. (2009).

APPROACH

The NWA requires the establishment of a national monitoring system that must provide for the collection of appropriate data and information necessary to assess water resources. Such a system must collect relevant information that contributes to the management of the resource in a desirable ecological condition

Initially the aim was to develop an Ecological Reserve Monitoring programme. This would have run separately to the River Health Programme (RHP). However, the implications of simultaneously operating two separate ecological monitoring programmes have serious resource implications. To mitigate this and still maintain an operational ecological monitoring programme that provides useful management information, integration of the ERM and RHP within an adaptive management approach is proposed (Kleynhans *et al*., 2009). **This forms the basis of the integrated Ecological Water Resource Monitoring (EWRM) approach**.

During Reserve determination studies, EcoSpecs are developed and specified in terms of the Resource Quality Objectives (RQOs) as per the Resource Directed Measures and EcoClassification process (Kleynhans and Louw 2007). This encompasses biological specifications or biocriteria (in the form of numerical values or narrative statements) that define a desired biological condition for a waterbody (Burton and Gerritsen, 2003). EcoSpecs then indicates the ecological detail that characterizes the EC.

TPCs indicate the values around the EcoSpecs that, if being approached would initiate more detailed investigation or even management action. TPCs are based on the acceptance that there is uncertainty as to accuracy or validity of EcoSpecs i.e. is deviation from EcoSpecs due to natural variation, sampling error, etc. In the context of EWRM, TPCs are regarded as early warning indicators of potential change from a particular Ecological Category (EC) to another (lower) EC.

EWRM operates within the following concepts (based on Elzinga *et al*., 1998):

- The reference condition is the natural or unimpaired condition of the system.
- The monitoring baseline is a series of measurements taken before the initiation of the impact or management activity and is used for comparison with the series of measurements taken after the management activity. If the Present Ecological State (PES) of the resource is unimpaired (natural), the reference will also be the baseline.
- It is important to assess whether there is a trend in the baseline, i.e. is it stationary or changing in a particular direction at the time when it is determined.
- This is the standard ("benchmark") against which future deviations can be compared.

Therefore the Present Ecological State (PES) of the system must be determined prior to management interventions. The PES will then serve as the baseline ecological state from which all changes can be measured and evaluated. i.e.:

PES = BASELINE = BASELINE ECOLOGICAL CATEGORY (BEC)

Management actions are designed to maintain, or attain (if different from the PES) the REC. These management actions relate to the management objectives which are described in terms of the flow and quality (physico-chemical) EcoSpecs. Additional land use objectives may also be described if there are non-flow related impacts that are contributing to the PES of the system and which will need to be improved in order to achieve the REC.

Therefore one must clearly distinguish between setting management objectives to achieve/maintain certain Ecological Categories in terms of the drivers (flow and water quality), and defining EcoSpecs for the biophysical response, that describes, in a different level of detail, the Ecological Categories.

In essence, during an EWR study, flow requirements (main driver) are defined that could result in a certain ecological state defined through an Ecological Category. These flow **requirements (main driver) inform the management objectives supported by the other driver component**s. Note that the word 'could' is

used as the biological responses to driver conditions are all predicted and must be tested through monitoring. Monitoring the ecological responses will test the predictions made during an EWR study. It furthermore will test whether adjustments to the EcoSpecs and TPCs are required and whether the overall management objective in terms of the REC (or class) is being achieved. It is therefore crucial that monitoring be driven by objectives as it forms the foundation of a monitoring project (cf. Elzinga *et al*., 1998):

The condition and response of the resource is therefore monitored to determine if the REC has been attained or maintained.

What is required at this stage is to provide detailed EcoSpecs and TPCs for the baseline, i.e. the BEC for the biological responses, physico-chemical variables and geomorphology.

The focus on this study is thus to provide the detailed EcoSpecs and to define the TPCs for (the BEC, i.e. the current or initial PES) at each EWR site on the Upper Vaal River System. Note that **TPCs are set within the PES to indicate the probability or relative risk of the BEC changing to a lower EC. The purpose of this is to implement management actions** to prevent this degradation, unless the Classification system has resulted in a state worse than the PES (BASELINE EC) being selected as the CLASS.

Note that the same level (qualitative/narrative to quantitative) of detail for the EcoSpecs is thus not set for the REC or any other EC as the focus is on the BEC. The level of EcoSpecs defined during the EcoClassification process will be sufficient during the initiation of monitoring. The EcoSpecs for ECs other than the PES are predictions and dependant on many driver variables and in essence, represents only one combination of driver conditions out of many that could result in this EC

RESULTS

EcoSpecs and TPCs are listed in detail in the main text for each EWR site for:

- Physico-chemical variables
- Geomorphology
- Riparian vegetation
- Fish
- Macroinvertebrates

These are highly detailed and quantified data that must be refined during an Adaptive Management process within EWRM. A summary of the EcoSpecs and TPCs in tabular form per site will be provided in the main report as the EcoSpecs chapter.

RECOMMENDATIONS

To date formal implementation of the monitoring step of the Reserve has not taken place (CJ Kleynhans, C Thirion, *pers. comm.*). Furthermore, there has been minimal (only informally on the Palmiet River and on a private dam in the Western Cape) implementation (with reference to the supply of the flows and management of other drivers to achieve the required EC) of the Ecological Reserve. This is of major concern as all EWRs, EcoSpecs; TPCs etc. are hypotheses until tested. With increased development and pressure on the water resources in this country there are no structures in place to monitor the further deterioration of our rivers. All methods related to monitoring and the identification of EcoSpecs and TPCs therefore require testing and refinement.

The Upper Vaal River system has very high demands imposed on it by the irrigation sector, as well as industrial and domestic sectors and forms the backbone of the economic hub of South Africa.

The RHAM was developed during 2007 - 2009 and it is recommended that a RHAM survey is undertaken at sites where applicable. It is foreseen that due to the size and nature of the Vaal River, the RHAM for wadeable rivers might not be possible at all sites. The semi-wadeable (still to be tested) RHAM could be

applicable. RHAM data may provide additional information on habitat suitability and the biota associated with this habitat.

No specific Ecological Reserve Monitoring has been initiated in this river system apart from the RHP monitoring conducted at EWR 9, 10, 11 and RE-EWR 2[1]. Immediate monitoring is necessary as the surveys undertaken during the Reserve study represent the baseline against which change is measured. These surveys were undertaken during 2007 and 2008 and it can already (pending changes in the catchments), not be applicable. The longer monitoring is delayed, the bigger the chance is that the baseline surveys will have to be repeated because of outdated data.

The main recommendation is that effective monitoring is started as soon as possible due to the economic importance of the Upper Vaal River and the presence of the Vredefort Dome Heritage site that falls within this study area below the Vaal River Barrage. The Upper Vaal River is exposed to regular water quality related impacts due to industrial activities that are not monitored as well as a failing municipal infrastructure that leads to pollution levels that lead to fish kills and the recreational activities being banned by the Department of Health, especially in the reaches below the Vaal Dam.

[1] According to Ms Hermien Roux and Mr Piet Muller, River Health Champions for the North West and Gauteng Provinces respectively (*Pers. comm.*, 2010).

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ACRONYMS

AEC	Alternative Ecological Category
ASPT	Average Score Per Taxon
BEC	Baseline Ecological Category
CD: RDM	Chief Directorate: Resource Directed Measures
CEC	Classification Ecological Category
CPUE	Catch Per Unit Effort
D: NWRP	Directorate: National Water Resources Planning Directorate
D:RQS	Directorate: Resource Quality Services
DSS	Decision Support System
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EC	Electrical Conductivity
EIS	Ecological Importance and Sensitivity
ERM	Ecological Resource Monitoring
EWR	Ecological Water Requirements
EWRM	Ecological Water Resource Monitoring
FD	Fast Deep
FDI	Flow Dependent macroinvertebrate
FRAI	Fish Response Assessment Index
FROC	Fish Frequency of Occurrence
FS	Fast Shallow
GAI	Geomorphology Assessment Index
ind/min	Individual/s per minute
MIRAI	Macro Invertebrate Assessment Index
MRU	Management Resource Unit
MV	Marginal Vegetation
MVI	Marginal Vegetation Macroinvertebrate
NAEHMP	National Aquatic Ecosystem Health Monitoring Programme
NWA	National Water Act
PES	Present Ecological State
Quat	Quaternary catchment
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RHAM	Rapid Habitat Assessment Method
RHP	River Health Programme
RQO	Resource Quality Objective
RU	Resource Unit
SASS5	South African Scoring System version 5
SD	Slow Deep
SRP	Soluble Reactive Phosphate
SS	Slow Shallow
TEACHA	Tool for Ecological Aquatic Chemical Habitat Assessment
TIN	Total Inorganic Nitrogen
TPC	Threshold of Potential Concern
TWQR	Target Water Quality Range
VEGRAI	Riparian Vegetation Response Assessment Index
WMA	Water Management Area
WMS	Water Management System

1 BACKGROUND AND INTRODUCTION

1.1 BACKGROUND

In order for the Department of Water Affairs (DWA) to make informed decisions regarding the authorization of future water use and the magnitude of the impacts of the present and proposed developments in the Vaal River System, higher levels of confidence is needed for the Reserve Determination within this study area. Therefore a Comprehensive Reserve determination study within Water Management Area (WMA) 8 has been undertaken to provide input to the Reconciliation studies and the integrated water quality management plan recently undertaken by the National Water Resources Planning Directorate (D: NWRP) of the DWA.

The Comprehensive Ecological Reserve Methodology followed the 8 - step Ecological Reserve process (Figure 1.1). This report summarizes step 7 of the process.

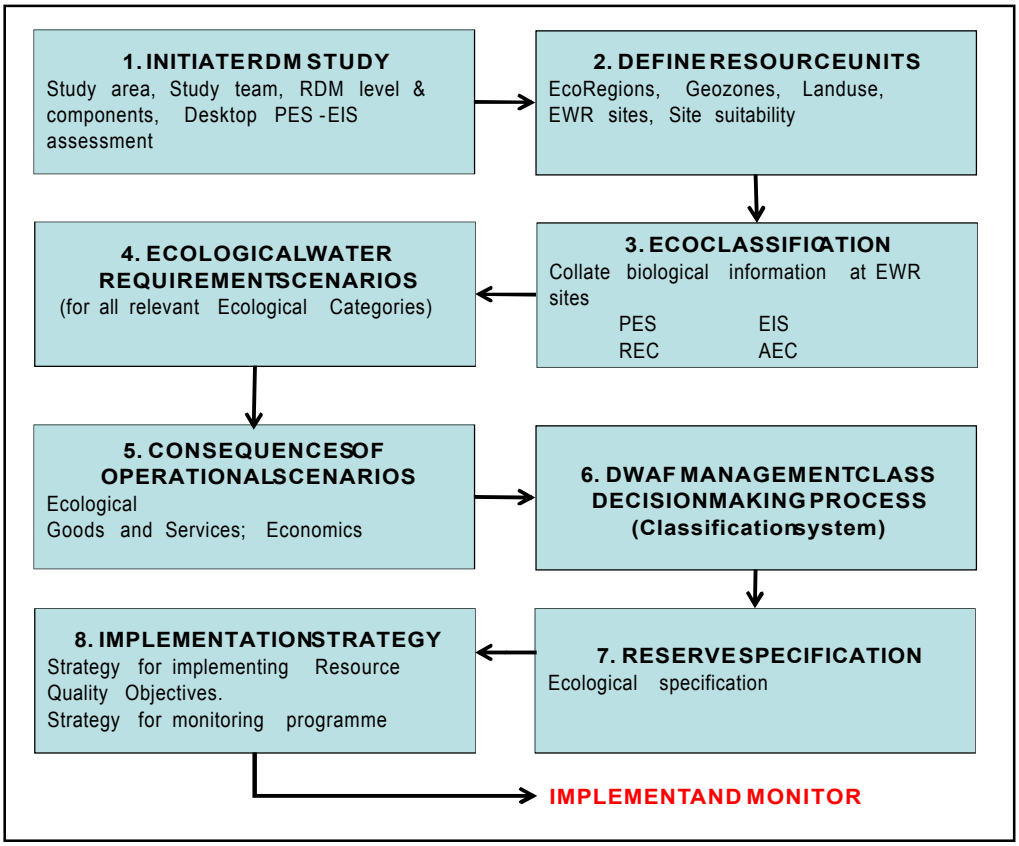

Figure 1.1 The 8-step Ecological Reserve procedure (DWAF, 1999)

1.2 STUDY AREA

The Upper Vaal WMA is one of three WMAs in the Vaal River catchment, which is the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers (DWAF, 2004).

The major tributaries in the Upper Vaal WMA include *inter alia* the Vaal, Klip, Watervals, Wilge, Liebenbergsvlei, Suikerbosrand, Klipspruit and Mooi Rivers and extend to the confluence of the Mooi and Vaal Rivers. It covers a catchment area of 55 565 km^2. The locality and characteristics of the Ecological Water Requirement (EWR) sites are provided in Table 1.1 and Figure 1.2.

Information on site selection and the Management Resource Units (MRUs) are provided in DWA (2008a) (Report RDM/WMA8C000/01/CON/0208).

Table 1.1 Locality of EWR sites for the Upper Vaal River System

EWR site number	EWR site name	River	National RHP site	Co-ordinates		EcoRegion (Level II)[1]	RU[2]	Quat[3]
				Latitude	Longitude			
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RE-EWR 2	Mooi	Mooi	Close to C2Mooi-Klerk	-26.2587	27.15973	11.01	RU Mooi B	C23G

1 Refer to Kleynhans *et al*. (2007) for EcoRegion description.
2 Resource Unit 3 Quaternary catchment

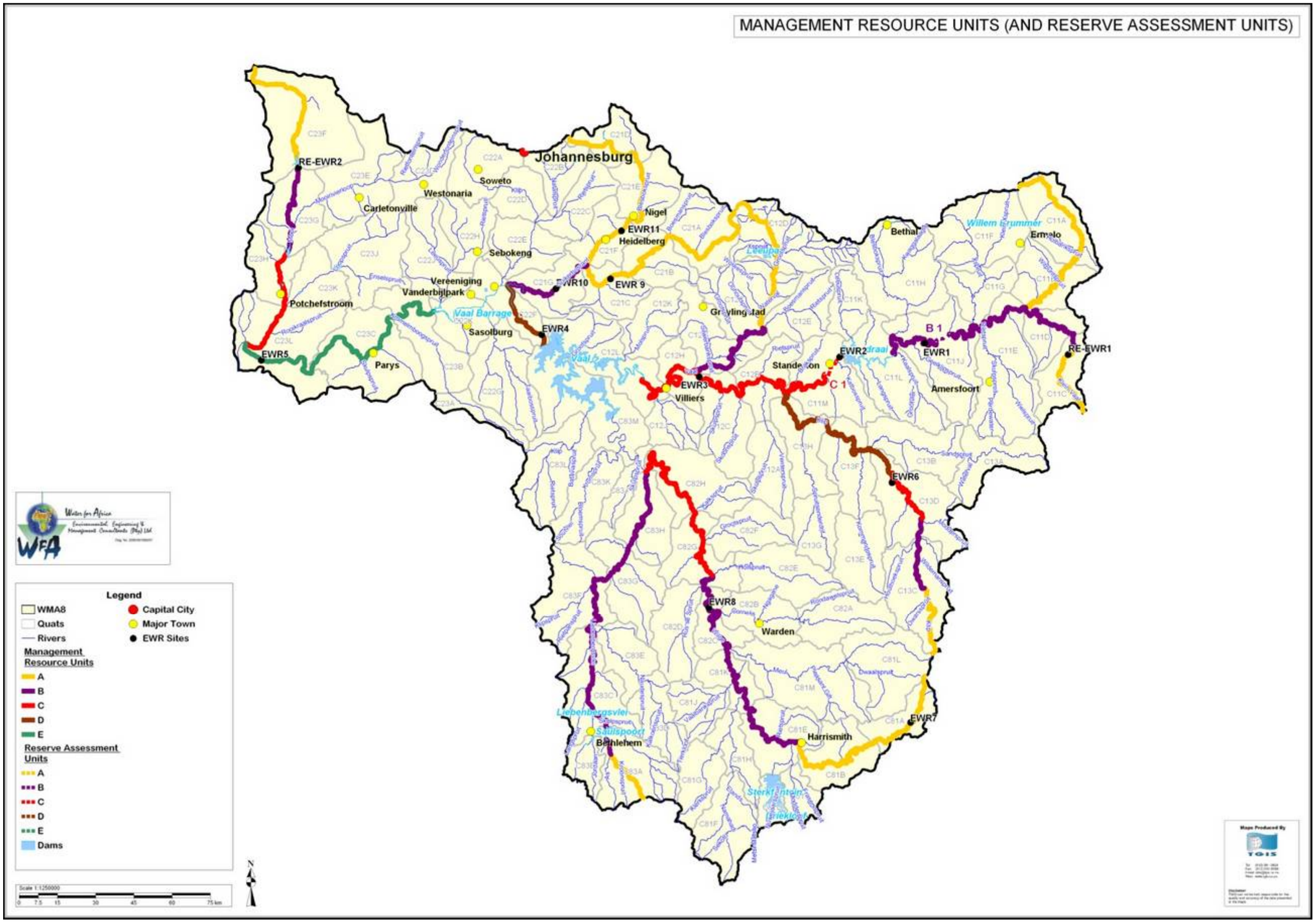

Figure 1.2 Locality of EWR sites and Management Resource Units of the Upper Vaal WMA

1.3 PURPOSE OF THE REPORT

The purpose of this report is to present the Ecological Specifications (EcoSpecs) and Thresholds of Potential Concern (TPCs) for each of the EWR sites on the Upper Vaal WMA. These EcoSpecs define the conditions that would occur under the Present Ecological State (PES). TPCs are provided to indicate worsening conditions. Where relevant, the conditions that describe the REC (when different than the PES) are also provided. This information forms the key inputs into an Ecological Water Resource Monitoring (EWRM) Program for these catchments. Further information on EcoSpecs and TPCs and their use in Ecological Water Resources Monitoring can be obtained from DWA (2009a), and Kleynhans *et al*. (2009).

1.4 OUTLINE OF THE REPORT

The contents and structure of this report is outlined below. All electronic information is available from RDM/WMA8C000/01/CON/0810 - Electronic information and data (DWA, 2010a).

1.4.1 Chapter 1: Introduction

This chapter.

1.4.2 Chapter 2: Approach

This chapter provides general background to the development and refinement of Ecological Water Resource Monitoring within the Ecological Reserve and RHP framework. Information is provided on ecological monitoring, EcoSpecs and TPCs, levels of monitoring, relevant terminology and interpretation of data. The approach and application of this monitoring to the Upper Vaal River system is also discussed.

1.4.3 Chapter 3: Methodology

This section describes the methods and data that were used to identify metrics and TPCs to determine the EcoSpecs and TPCs for the different Reserve components.

1.4.4 Chapter 4 – 16: Determination of EcoSpecs and TPCs

These chapters provide results of different EWR scenarios with respect to low and high flows for the respective EWR sites. Aspects covered in these chapters are component and integrated/stress curves, generating stress requirements, general approach to high flows, final results and confidence in the final results.

1.4.5 Chapter 17: Recommendations

Recommendations are made in terms of the current tools available for monitoring and the application thereof.

1.4.6 Chapter 18: References

1.4.7 Appendix A: Additional monitoring information for future Ecological Water Resource Monitoring

Information on geomorphology and fish monitoring is provided and provides valuable information for future planned ecological water resource monitoring.

2 APPROACH

The EWRM (referred to previously as the Ecological Reserve Monitoring Programme), was first developed as an initial protocol during the Kromme River Reserve study in 2006 (DWAF, 2006a). Further development was undertaken during the Operationalisation of the Reserve study where the Rapid Habitat Assessment Method (RHAM) (DWAF, 2009b) was developed and the initial concepts of the Monitoring Decision Support System deliberated. The intention with the development of RHAM was to address the capacity and funding shortages by simplifying monitoring techniques as much as possible.

It must be noted that no RHAM assessment was undertaken for this study and therefore the Ecological Specifications (EcoSpecs) and associated Thresholds of Potential Concern (TPC) represents the baseline as measured during the 2008 EWR survey.

2.1 BACKGROUND TO ECOLOGICAL WATER RESOURCES MONITORING (SUMMARISED FROM DWAF, 2009a)

The National Water Act (NWA, Act No. 36 of 1998) requires the establishment of a national monitoring system that must provide for the collection of appropriate data and information necessary to assess water resources. Such a system must collect relevant information that contributes to the management of the resource in a desirable ecological condition by providing information on:

- Compliance with Resource Quality Objectives (RQOs). This relates to Ecological Reserve Monitoring following on from the specification of Ecological Water Requirements (EWRs). The EWR process, results in an extensive amount of data at a relatively limited number of sites that can be used for ERM to determine if the Recommended Ecological Category (REC) following from the EWR is achieved.
- The health of aquatic ecosystems. This relates to the National Aquatic Ecosystem Health Monitoring Programme (NAEHMP) and in this particular situation, to the River Health Programme (RHP) part of the NAEHMP. The RHP is primarily aimed at providing information on the health or integrity of rivers for national state of the rivers reporting and as input to resource management at a large number of sites based on biological responses.

Initially the aim was to develop an Ecological Reserve Monitoring programme. This would have run separately to the River Health Programme (RHP). However, the implications of simultaneously operating two separate ecological monitoring programmes have serious resource implications. To mitigate this and still maintain an operational ecological monitoring programme that provides useful management information, integration of the ERM and RHP within an adaptive management approach is proposed (Kleynhans *et al*., 2009). **This forms the basis of the integrated Ecological Water Resource Monitoring (EWRM) approach**.

2.1.1 Ecological monitoring

Ecological monitoring is the collection and analysis of repeated observations or measurements **to evaluate changes in the condition of the resource and the progress towards meeting the management objective (Elzinga *et al*., 1998)**. In terms of EWRM, it is the measurement of EcoSpecs (ecological specifications) to determine if the Ecological Category is attained (Kleynhans *et al.,* 2009). EWRM operates within the following concepts (based on Elzinga *et al*., 1998):

- The reference condition which is the natural or unimpaired condition of the system.

- The monitoring baseline which is a series of measurements taken before the initiation of the impact or management activity and used for comparison with the series of measurements taken afterward.
- Response monitoring occurs at a particular detail, frequency and intensity as guided by the Ecological Importance and Sensitivity (EIS) of the resource. In the case of Ecological Reserve implementation, the scale and potential impact of the development also plays a role in the frequency and detail included. Response monitoring results are evaluated by analysis within a management objective framework. This allows measurement of how the resource is changing over time, i.e. to measure the trend.
- Implementation monitoring assesses whether the activities are carried out as designed. Implementation monitoring can also identify which variables are most likely to be causing a change in the resource, and help eliminate from consideration some potential causes of change (Kershner, 1997; Elzinga *et al*., 1998). In terms of the Ecological Reserve this would, inter alia, refer to whether flows are released as was specified for the attainment of a particular Ecological Category (EC).
- Effectiveness monitoring measures whether RQOs (the Ecological Category in terms of EcoSpecs) are attained by following the particular management scenario (Kershner, 1997).

If the EC decreases over a period of time and the cause is unknown, more intensive monitoring or research may be initiated to determine the cause of the decrease. If a cause for decrease is suspected, appropriate management intervention may be indicated (Elzinga *et al*., 1998).

2.1.2 EcoSpecs and Thresholds of Potential Concern

EWRM must be undertaken within a structured Decision Support System (DSS) framework following the principles of Adaptive Management. The purpose of the DSS is to provide a decision framework within which monitoring results can be interpreted in terms of the attainment of objectives set for the condition and integrity of the resource. This relates directly to EcoSpecs and Thresholds of Potential Concern (TPCs) (Bestbier and Rogers, 1997) formulated to assess attainment of an Ecological Category. Conclusions emanating from the DSS will provide guidance on the management of the resource (Cormier and Suter, 2008).

2.1.3 Different levels of monitoring

Due to capacity and resource limitations, all EWRM sites cannot always be monitored at the same and highest intensity that may be desirable. These restrictions necessitate different levels of monitoring and require the setting of TPCs for the different levels of monitoring. It follows that a relatively low intensity monitoring survey will provide TPCs with a larger margin of error than surveys done at a more intensive level. However, the results of TPC assessment from a lower to a higher level of monitoring must be linked. These concepts form the basis of the DSS system.

Within the Resource Directed Measures (RDM) “Operationalisation of the Reserve” project (DWA, 2009a), it was recognised that to ensure the effective implementation of EWRM, all efforts must be made to design a programme and methods that are as cost-effective as possible. The hierarchical approach within the DSS system supports this. The need for pragmatic and easy to apply methods to monitor instream habitat led to the development of the Rapid Habitat Assessment Method (RHAM) (DWA, 2009b). This method aims to provide a rapid approach to assess instream habitat conditions in wadeable and to a more limited degree, non-wadeable streams. RHAM data collected during the setting of the baseline (and the determination of the PES) is used to assess

habitat suitability for indicator instream biota (fish and macroinvertebrates) under the conditions prevailing during the survey and is fundamental to the development of EcoSpecs and in the setting of the accompanying TPCs that indicate the suitability of the habitat to sustain such biota. The premise of the RHAM is that suitable habitat conditions will indicate the likely presence, abundance and frequency of occurrence of particular biota. Baseline conditions are used to assess the possible future change in habitat conditions and the derived impact on the indicator biota. Available data and expert knowledge is used to associate particular habitat conditions with different indicator biota and the relevant ECs.

The RHAM is also supported with the development of a rapid approach to use diatoms as TPCs for physico-chemical changes. The diatom process is still in its infancy and must be tested. This approach was designed for a non-specialist and a manual is available.

The DSS proposed for ecological water resource monitoring and management is based on monitoring and interpreting resource quality at five levels of detail. This framework is used to construct a DSS based on baseline specification, EcoSpecs and TPCs. A prototype DSS is illustrated below (Figure 2.1).

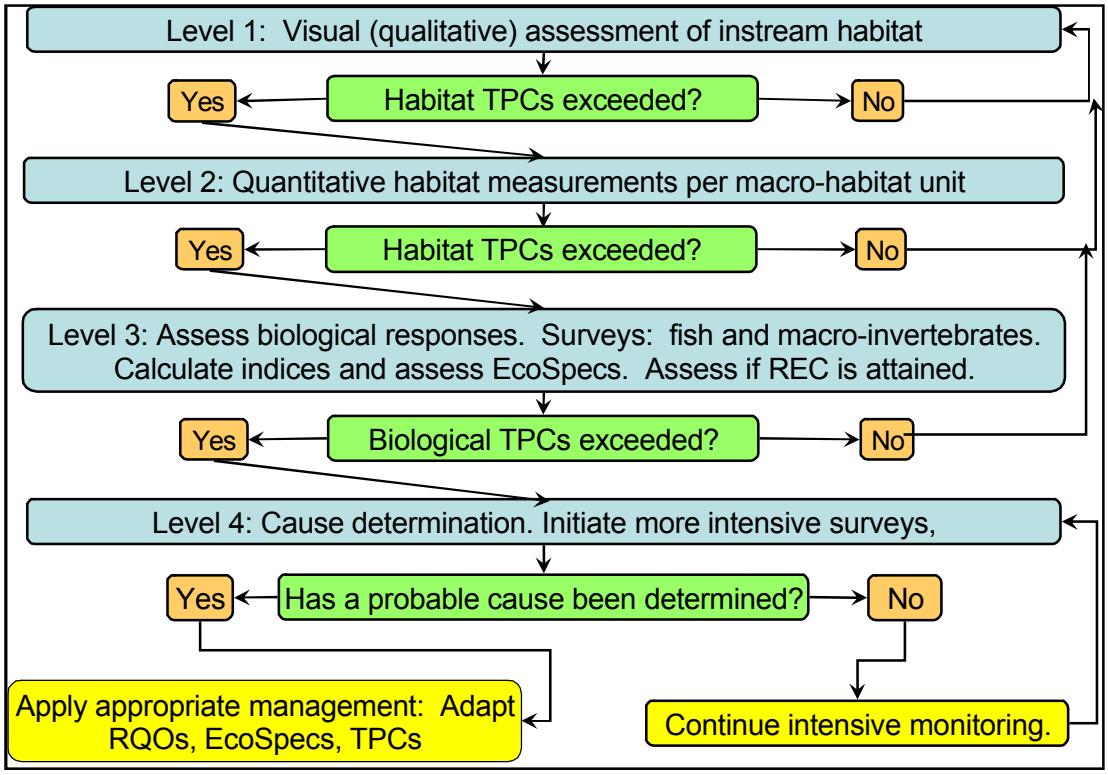

Figure 2.1 Elements of a prototype DSS

The following work is in development by DWA, Directorate: Resource Quality Services (D:RQS), and will be available later this year:

- DSS framework.
- Using habitat information from the RHAM to determine fish EcoSpecs.
- Using habitat information from the RHAM to determine macroinvertebrate EcoSpecs.

Sufficient information on the baseline and the collection of data during monitoring is however available and it is strongly recommended that monitoring is implemented as soon as possible. It must also be pointed out that the information generated during an EWR

study should serve as the baseline. This means that monitoring must be initiated immediately after such a study ends, or else a new baseline will have to be collected at a later date.

2.2 ECOSPECS AND TPCs (SUMMARISED FROM DWA, 2009a)

EcoSpecs and TPCs are described in the Table 2.1 below.

Table 2.1 Purposes and principles of EcoSpecs and TPCs (from DWA, 2009a)

ECOSPECS	TPCs
PURPOSES	
• During EWR studies, EcoSpecs are developed and specified in terms of the RQOs as per the Resource Directed Measures and the EcoClassification process (Kleynhans and Louw, 2007). This encompasses biological specifications or Biocriteria that are numerical values or narrative statements that define a desired biological condition for a waterbody (Burton and Gerritsen, 2003). A certain level of habitat integrity (specified as Habitat criteria) is required to attain a particular biological condition for a water body. EcoSpecs then indicates the ecological detail that characterizes the EC. • To establish clear goals relating to the ecological quality of the relevant water resources. • Where resources, for instance, need a high level of protection, a strict set of objectives that will represent a low risk of damage, will be set. • Once the management class of a water resource has been decided, the objectives for protection of basic human needs and ecological integrity take precedence in cases where the objectives for other uses, or for impacts, may conflict with the requirements for protection.	TPCs indicate the values around the EcoSpecs that, if being approached would initiate more detailed investigation or even management action. TPCs are based on the acceptance that there is uncertainty as to accuracy or validity of EcoSpecs i.e. is deviation from EcoSpecs due to natural variation, sampling error, etc. In the context of EWRM, TPCs are regarded as early warning indicators of potential change from a particular EC to another (lower) EC.
PRINCIPLES	
EcoSpecs must be quantifiable, measurable, verifiable and enforceable and ensure protection of all components of the resource, which make up ecological integrity. The critical components of the EcoSpecs include: • Requirements for water quantity. Flow requirements for a river reach, estuary, and/or water level requirements for standing water or groundwater are included. Groundwater level requirements to maintain spring and base flow in rivers and other ecological features are also considered. • Biocriteria and Habitat criteria that are derived from RQOs and are clear and measurable specifications of ecological attributes (flow, physico-chemical attributes and biological integrity that reflect the health, community structure and distribution of aquatic biota). EcoSpecs define the EC and serve as an input to RQOs. EcoSpecs refer only to ecological information whereas RQOs include economic and social objectives	TPCs are upper and lower levels along a continuum of change in selected environmental indicators and are used and interpreted according to the following guidelines (Rogers and Bestbier, 1997): • When a TPC level is reached (or when modelling predicts it will be reached), it prompts an assessment of the causes of the extent of the change. • Assessment of the causes provides the basis for deciding whether management action is needed or if the TPC needs to be recalibrated. TPCs provide management with strategic goals or endpoints within which to manage the system. • TPCs form the basis of an inductive approach to adaptive management, and are invariably hypotheses of limits of acceptable change in ecosystem structure, function and composition. • The validity and appropriateness of TPCs are always open to challenge and they must be adaptively modified as understanding and experience of the system being managed increases. It follows that more detailed monitoring surveys would increase the confidence in the validity of a TPC (i.e. narrow the uncertainty). This principle is built into the DSS by considering different levels of monitoring surveys.

2.3 APPROACH FOR APPLYING THE PRINCIPLES OF EWRM, ECOSPECS AND TPCs WITHIN THIS STUDY

The principles and conceptual approaches to EWRM have been under development since 2006 (DWAF, 2006a). However, very few monitoring approaches have been tested and an appropriate DSS is still being developed. Proper testing within an adaptive management framework can only be done if EWRM for Reserves is implemented. Within this study, and with the guidance of the

developers of the methods in D:RQS, these conceptual approaches needed to be translated into a practical approach for defining DETAILED EcoSpecs that can be used in the monitoring process.

Ecological monitoring is the collection and analysis of repeated observations or measurements to evaluate changes in the condition of the resource and the progress towards meeting the management objective (Elzinga *et al.,* 1998). In terms of EWRM it is the measurement of EcoSpecs (ecological specifications) to determine if the REC is attained (Kleynhans *et al*., 2009).

EWRM operates within the following concepts (based on Elzinga *et al*., 1998):

- The reference condition is the natural or unimpaired condition of the system.
- The monitoring baseline is a series of measurements taken before the initiation of the impact or management activity and is used for comparison with the series of measurements taken after the management activity. If the PES of the resource is unimpaired (natural), the reference will also be the baseline.
- It is important to assess whether there is a trend in the baseline, i.e. is it stationary or changing in a particular direction at the time when it is determined.
- This is the standard ("benchmark") against which future deviations can be compared.

Therefore the Present Ecological State (PES) of the system must be determined prior to management interventions. The PES will then serve as the baseline ecological state from which all changes can be measured and evaluated. i.e.:

PES = MONITORING BASELINE = BASELINE ECOLOGICAL CATEGORY (BEC)

Management actions are designed to maintain, or attain (if different from the PES) the REC. These management actions relate to the management objectives which are described in terms of the flow and quality (physico-chemical) EcoSpecs. Additional land use objectives may also be described if non-flow related aspects are contributing to the PES of the system.

During the EWR Scenario phase, different flow regimes are identified for a range of ECs. These serve as the flow RQOs or flow EcoSpecs for different ECs. Physico-chemical EcoSpecs for different ECs are also broadly defined during EcoClassification, but are quantified as far as possible during the EcoSpec phase of the study. During and after the testing of various operational and future development scenarios, as well as the Classification process or any surrogates of this, a final scenario will be signed off as the Reserve. If this scenario is to maintain or improve the EC in the system, the EcoSpecs associated with this scenario are used to describe the management objectives for the system.

Therefore one must clearly distinguish between setting management objectives in terms of the drivers to achieve/maintain certain Ecological Categories, and defining EcoSpecs for the biophysical response, that describes, in different level of detail, the Ecological Categories.

In essence, during an EWR study, flow requirements (main driver) are defined that could result in a certain ecological state defined through an Ecological Category. These flow **requirements (main driver) inform the management objectives supported by the other driver component**s. Note that the word 'could' is used as the biological responses to driver conditions are all predicted and must be tested through monitoring.

Monitoring the ecological responses will test the predictions made during an EWR study. It furthermore will test whether adjustments to the EcoSpecs and TPCs are required and whether the overall management objective in terms of the REC (or class) is being achieved. It is therefore crucial that monitoring be driven by objectives as it forms the foundation of a monitoring project (cf. Elzinga *et al*., 1998).

The condition and response of the resource is therefore monitored to determine if the REC (or PES) has been attained or maintained.

2.4 ECOLOGICAL CATEGORIES: TERMINOLOGY RELEVANT TO EWRM (provided by CJ Kleynhans)

Present Ecological State (PES): The PES is based on the determination and integration of the condition of system drivers and the biological responses. This represents the ecological condition at the time of the survey. Logically there can only be one PES and that is the most recent determination.

Baseline Ecological Category (BEC): The baseline functions as a standard or benchmark against which future changes of the Ecological Category can be measured. The baseline is determined using the PES survey information that is collected during the EcoStatus determination for the EWR or RHP (EWRM). The PES used for this purpose is supplemented by historical data but the primary data source is the surveys and data collation for EcoClassification. The PES data collected and analyzed for this purpose is used to set or establish the baseline. The baseline is fixed as the Baseline Ecological Category (BEC).

Recommended Ecological Category (REC): This is the EC that is recommended based on the EIS and the attainability of the EIS.

Ecological Category (EC): The Ecological Category is a generic term that refers to the BEC or the REC or any alternative categories. It should preferably only be used to refer to the process of Ecological Category determination (EcoClassification).

2.5 ECOLOGICAL CATEGORIES: MONITORING DATA INTERPRETATION (provided by CJ Kleynhans)

The relationships described in 2.5.1 and 2.5.2 (between the BEC and the REC in terms of defining and quantifying EcoSpecs and TPCs) is illustrated in Figure 2.2 (provided by CJ Kleynhans).

2.5.1 Steps to follow when the REC is the same as the BEC (BEC (PES) = REC)

The EcoSpecs that represent the REC are directly derived from the BEC, e.g. both the biological indicator metrics and the particular associated physico-chemical metrics. EcoStatus models are run to indicate likely change points, e.g. where the REC may start to degrade to a lower category. This is done during the EcoClassification phase. These changes are linked with shifts in the numerical or index value of indicator metrics and are Thresholds of Potential Concern (TPCs). TPCs refers to upper and/or lower values around a metric that will preferably provide an early indication that the metric that represent an EcoSpec, may be deteriorating which may result in a degradation of the EC. The statement regarding the upper value must not be confused with the upper percentage value of an Ecological Category. The lower and upper value of a metric can refer to e.g. temperature where the increase in temperature can result in a lower EC.

2.5.2 Steps to follow when the REC is higher than the BEC (BEC (PES) <REC)

The BEC is used as the basis to derive the indicator metrics for EcoSpecs and TPCs by following the EcoClassification and running the relevant EcoStatus models for the REC. The relevant metrics are determined during the EcoClassification workshop.

a) BEC improvement and attainment of REC: Define and quantify EcoSpecs and metric values that would indicate attainment of the REC or a trend in the improvement of the BEC (not TPCs) as determined during the EcoClassification workshop.

b) BEC degradation: Define and quantify EcoSpecs and metric values that would indicate a decrease in the BEC. Define and quantify TPC maximum and/or minimum values that would indicate a decline in EcoSpec metrics and possible decline in the BEC.

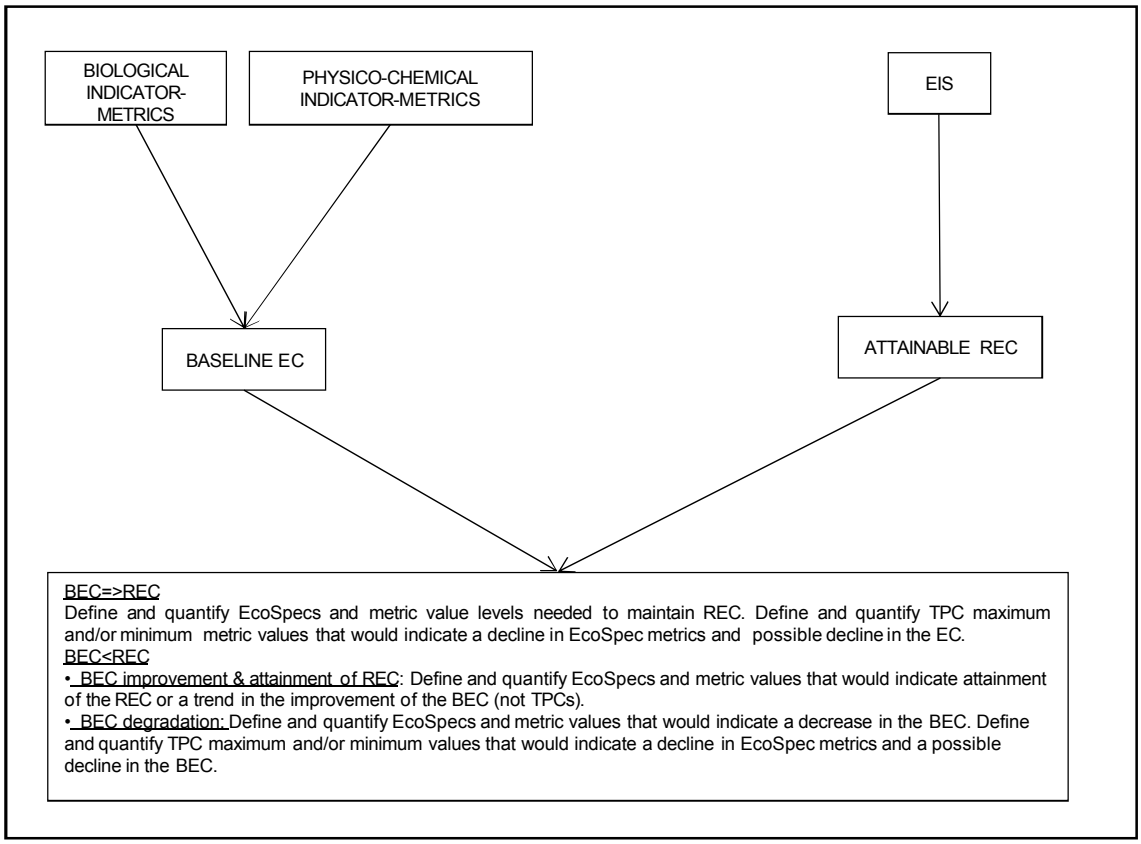

Figure 2.2 Relationship between BEC and the REC in terms of defining and quantifying EcoSpecs and TPCs

2.5.3 Implications of the Classification system and the Class on steps for setting EcoSpecs and TPCs

The ultimate Class determined through the application of the Classification System could be the BEC (PES), REC or a different EC. This Class is referred to as the Classification Ecological Category (CEC). The following scenarios could be relevant:

- BEC = CEC = REC
- BEC = CEC < REC
- BEC = REC > CEC

During EcoClassification an Alternative EC (AEC) is set and described and this caters for the situations where the CEC is a lower EC than the PES or BEC.

2.6 ECOSPEC DETERMINATION AS APPLIED IN THIS STUDY (written by D Louw)

Reference conditions, the Present Ecological State (PES), the Recommended Ecological Category (REC) and Alternative Ecological Categories (AECs) have been determined (DWA, 2009c) during the EcoClassification process. **This provides the broad level of EcoSpecs for the biophysical components for each EC addressed during EcoClassification. It also provides the information on the biological indicator metrics (see sections above). During the EWR scenario workshop, the flow EcoSpecs for each EC (the scenario refers to different ECs) was defined (DWA, 2009d).**

What is required at this stage is to provide detailed EcoSpecs and TPCs for the baseline, i.e. the BEC for the biological responses, physico-chemical variables and geomorphology. As further clarification, the EcoStatus EC and component ECs that represent the BEC must be quantified to provide detail EcoSpecs to be used in the EWRM process. Irrespective of what the REC or the EC that will result from the implementation of the classification process is, what is being monitored is the baseline, i.e. the BEC. Therefore, to determine whether the BEC is changing, one needs to provide the detailed EcoSpecs and to define the TPC that will, within an EWRM DSS, indicate whether the BEC is being maintained, improved, or degrading.

The focus on this study is thus to provide the detailed EcoSpecs and to define the TPCs for (the BEC, i.e. the current or initial PES) at each EWR site on the Upper Vaal River system. Note that **TPCs are set within the PES to indicate the probability or relative risk of the BEC changing to a lower EC. The purpose of this is to implement management actions** to prevent this degradation, unless the Classification system has resulted in a state worse than the PES (BASELINE EC) being selected as the CLASS.

The same level (qualitative/narrative to quantitative) of EcoSpecs is not set for the REC or any other EC as the focus is on the BEC. The level of EcoSpecs defined during the EcoClassification process will be sufficient during the initiation of monitoring. The EcoSpecs for ECs other than the PES are predictions and dependant on many driver variables and in essence, represents only one combination of driver conditions out of many that could result in this EC. (Note that during the EcoClassification process, only the most LIKELY hypothetical qualitative scenario is described in terms of changes in drivers). To define these EcoSpecs in more detail than the BEC would therefore be impractical, as these other ECs must be achieved first, before the detailed level of EcoSpecs can be defined. In the hypothetical case where the REC is an improvement of the BEC, the detailed EcoSpecs and a new TPC for this EC must be defined at that stage. Real conditions, data and specifications will then be available of how the biota has responded to the implementation of management objectives and this will allow for detailed EcoSpecs and a TPC to be set.

The concepts of the EcoSpecs and TPCs are described in a hypothetical example (Figure 2.3) where the PES (BEC) is a C and the REC a B.

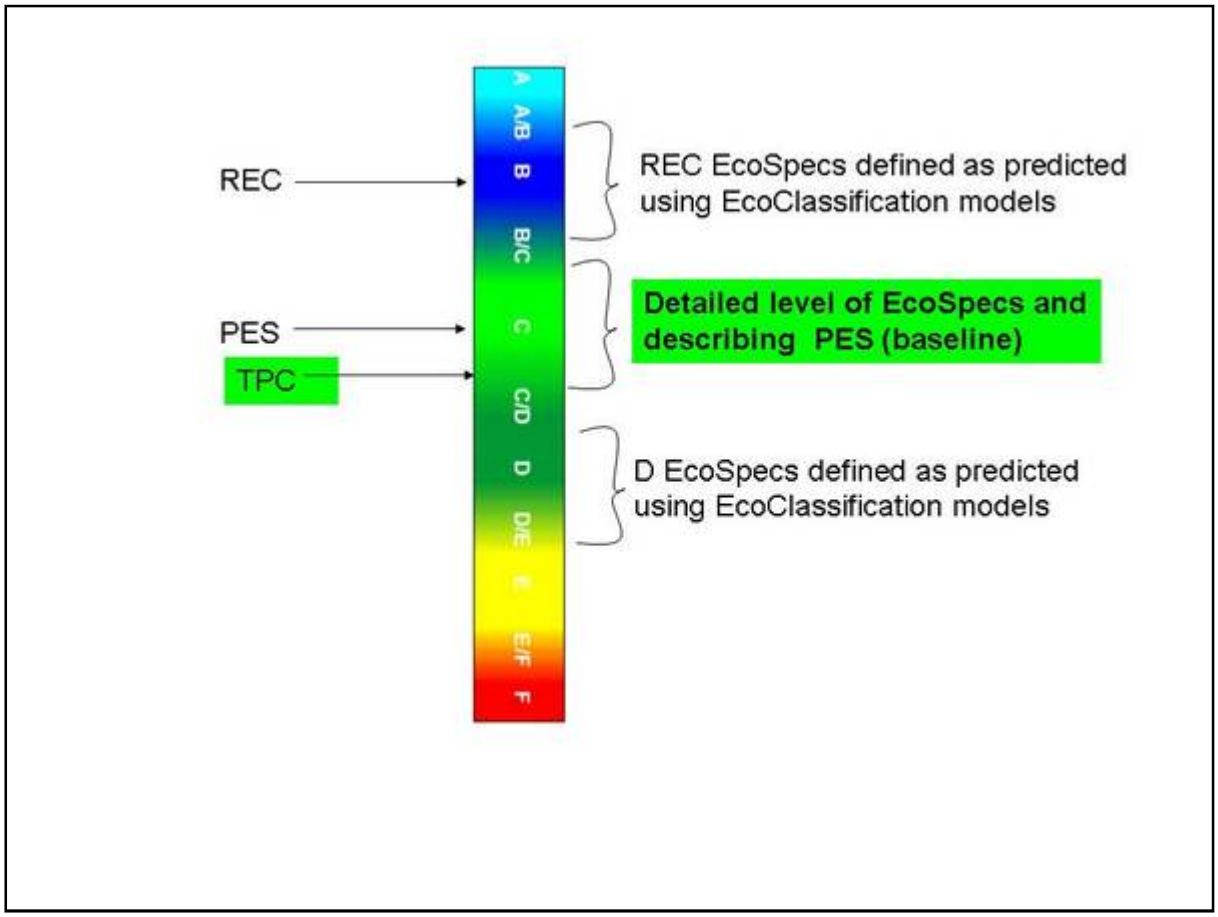

Figure 2.3 Example showing how the relationship between the EcoSpecs, TPCs and ECs

3 METHODOLOGY

This section describes the methods and data that were used to determine the EcoSpecs and TPCs for the different Reserve components.

3.1 GEOMORPHOLOGY

Authored by MW Rountree

3.1.1 Background

Reserve monitoring is required to assess the efficacy of the requested flows for the environment. Monitoring should thus be focussed on those descriptors of the system that are sensitive to flow alterations. However, the geomorphological condition at a monitoring or EWR site can be affected by both the upstream flow alterations as well as adjacent landuse activities. Thus there may not always be simple cause-effect relationships between geomorphological descriptors and flow conditions, and one should be aware of possible changes to river geomorphology that are not directly flow related. Additionally, antecedent events such as large natural flood events may temporarily create apparently undesirable changes that are not directly related to the provision of EWR flows at a site. Monitoring of the geomorphological conditions must therefore take into account the number and size of recent floods and the impacts of catchment and riparian landuse in addition to the flow record and provision (or lack) of the requested EWR flows.

The descriptors that were selected for geomorphology were chosen based on their assumed potential to indicate responses to flow changes. Three categories of descriptors were identified:

- Hydrology.
- Low flow season bed material composition, and;
- Channel form and gross morphology.

Once the descriptors were identified, the ranges of conditions expected for the Recommended Ecological Category (REC), which in this study for geomorphology is usually synonymous with the Present Ecological State (PES) were determined.

3.1.2 EcoSpecs and TPCs

In general, the Upper Vaal and its tributaries can be described as supply (sediment) limited systems, in that there is much more streampower available to erode than there is sediment available to be moved. Consequently, the morphologies of these rivers are somewhat resilient to moderate increases or decreases in overall flow. A notable exception is EWR 7 which represents the river within the upper Wilge wetland. This is an alluvial, depositional system which is HIGHLY sensitive to flow changes.

For all other sites however, the rates and ranges of morphological adjustment that can be expected from the morphological descriptors for monitoring (bed material composition and channel morphology) are likely to be relatively small due to the low slopes and resistant (often bedrock-controlled) nature of the bed and banks of the river reaches.

EcoSpecs and TPCs have been generated for the hydrology, bed material composition and channel morphology metrics. These metrics were identified based on metrics that are critical and rapidly responding and which are:

- Relevant for assessing and monitoring the condition of the river geomorphology, and/or represent critical habitats for instream biota; and
- Feasible and cost-effective to collect as part of a monitoring programme.

Hydrology requirements were however covered by the flow EcoSpecs provided as the EWRs for the EWR sites. EcoSpecs and TPCs were set based on a field and desktop assessment of the site visit undertaken during the low flow season in 2008.

3.2 PHYSICO - CHEMICAL VARIABLES

Authored by Dr R Heath

3.2.1 Approach

This Section details the Ecological Specifications for the maintenance of the Water Quality component of the Reserve for each EWR site. These are the values of water quality parameters (usually maximum concentrations) that should not be exceeded in order to meet the water quality component of the Recommended Ecological Category (REC).

The water quality EcoSpecs and TPCs were derived using methods from DWAF (2006b); DWAF (2006c) and Muller and Scherman (2007). The Thresholds of Potential Concern (TPCs) which are "triggers" that indicate management action (further investigation into the cause of a potentially problematic water quality constituent) is required, and the monitoring activities that should be undertaken in order to measure the EcoSpecs and TPCs are also described.

The Present Ecological State for water quality (WQ PES), the Overall PES, the Ecological Importance and Sensitivity (EIS), and the Recommended Ecological Category (REC) for EWR sites at which a Comprehensive Reserve determination was done are given in Table 3.3.

The approach used for the Upper Vaal WMA was as supplied by Dr Patsy Scherman and was used for the Inkomati study (P Scherman, *pers. comm.,* January 2010) (DWA, 2010b).

The EcoSpecs and TPCs, an explanation of water quality concerns and recommendations for monitoring water quality at each of the sites is provided in the various report chapters. The following observations, however, are relevant to all the sites.

The Physico-Chemical Driver Assessment Index (PAI) model can be used to disaggregate the overall water quality category into individual scores for each variable (e.g., dissolved oxygen [DO] or nutrients) so as to manage specific variables of concern, but in this study, because the water quality category required to attain the REC is the same as the PES WQ and therefore this procedure was not required (refer to the DWA, 2009c and DWA, 2010a; Appendix D and electronic information for the PAI tables generated during the EcoClassification process).

Thus the approach followed in specifying the EcoSpecs for the REC was generally to use the boundary value as given in the Riverine RDM Report (DWAF, 2009c; Appendix D) for the current PES category for each variable. In cases where there was a negative trend for a water quality variable or where the variable was currently in a lower category than that required to achieve the REC (usually Soluble Reactive Phosphorus [SRP]), the EcoSpec was to improved by half or one category.

Since the hydrological regime under the REC is designed to maintain PES in instances where the recommendation is to maintain the present state, major changes in water quality as a consequence of altered flow are not expected. Changes in water quality in the future are more likely to be a consequence of changes in landuse (diffuse pollutants) or new point - sources of pollutants. Nevertheless it is important to keep in mind the following general relationships between flow and water quality:

- A decrease in flow is likely to result in increased concentrations of chemical constituents as a consequence of the reduced dilution capacity of the system for variables that have a direct relationship with flow, e.g. salts. This relationship does not apply to variables such as nutrients.
- The range in daily instream temperature is likely to increase if flow is reduced due a reduction in the buffering capacity. Thus during the summer, hotter day temperatures can be expected and during the winter, colder temperatures can be expected during the night.
- Dissolved oxygen (DO) concentrations will *decrease* as water temperature increases. Dissolved oxygen concentrations may also be lowered if flow is reduced due to reduction of aeration, a consequence of fewer riffle areas.
- pH is unlikely to show a marked change in response to changes in flow.

Note: There are few data for the catchments under consideration for DO, temperature, turbidity or Chlorophyll a, and monitoring of these variables is highly recommended (possibly by installing data loggers for DO and temperature). As such, they have been included in the monitoring programme.

There was an incompatibility between water quality data obtained from the DWA Water Management System (WMS) database and the data format required to run the model "TEACHA" (Tool for Ecological Aquatic Chemical Habitat Assessment). As a result, the theoretical concentrations of the salts that are normally examined during a water quality Reserve study ($MgSO_4$, Na_2SO_4, $MgCl_2$, $CaCl_2$, and NaCl) could not be calculated.

The water quality data used for this assessment is indicated in Table 3.1.

Table 3.1 Location of the water quality sites related to the Upper Vaal EWR sites

Major River/Dam unit	EWR site	Reason: Water Quality Issues
Upper reaches Vaal River (from origin) Grootdraai catchment	EWR 1; RE-EWR 1	Fairly good quality water. Some impacts detected: Some increase in TDS from origin - could be diffuse impacts originating from coal mines. Witpuntspruit tributary is an issue - acid mine drainage (low pH, high sulphates).
Vaal River (downstream of Grootdraai Dam to just upstream of Waterval confluence) Klip River Wilge River	EWR 2	1. Klip River - Agricultural runoff (nutrients and turbidity). 2. Wilge (main stem) Seasonal variation is absent due to continuous releases from Katse Dam. Some agricultural runoff (nutrients) in Vaal dam and turbidity. 3. Vaal River - Fairly good quality, Grootdraai Dam water.
Vaal River (between Waterval River confluence and Vaal Dam)	EWR 3	High TDS and high Total Phosphates. Impact of Waterval River (high salinity and nutrient concentrations) observed in main stem.
Vaal River (outflow Vaal Dam to Lethabo weir)	EWR 4	Good water quality (Vaal Dam water). Salinity impacts from Waterval (high salinity and nutrient concentrations) attenuated by Vaal Dam. Increasing trend in phosphate concentrations. Potential for algal blooms increasing mainly due to diffuse agricultural runoff. Chlorophyll-a seasonal variability.
Mooi River (downstream of Loopspruit confluence to Vaal River confluence); and Vaal River downstream of Parys to just upstream Mooi River confluence	EWR 5	High salinity due to mine water decants from Witwatersrand. High nutrients due to waste water treatment work discharges and informal settlement runoff. Potential for algal growth – rooted macrophytes, filamentous, exotic floating macrophytes (Water hyacinth) and single cell blooms. Occasional high metal values. Diffuse runoff from unsewered areas leads to seasonally high microbiological contamination.
Klip River	EWR 6	Klip River - Agricultural runoff (nutrients and sediments). Possible acid mine drainage impacts from Majuba coal mine and power stations.
Wilge River	EWR 7	Upper Wilge extensively modified by agriculture. Turbidity due to highly erodable soils. EWR 7 is about 3.5 km upstream of the confluence of the Wilge and Bedford streams

Major River/Dam unit	EWR site	Reason: Water Quality Issues
		where the proposed Braamhoek pump station will impact. The proposed upper reservoir is located in the Bedford stream.
Vaal River (downstream Grootdraai Dam to just upstream of Waterval River confluence)	EWR 8	Vaal River - Fairly good quality, Grootdraai Dam water. Middle Wilge - Point sources WWTW (Harrismith, Industriqwa and Tshiane). Diffuse runoff from Harrismith, urban, industrial (Industriqwa), agriculture. Anthropogenic sources damming/weir (water abstraction for purification – Harrismith), water abstraction by tankers and angling. Sterkfontein Dam releases potential impacts such as turbidity, habitat loss, cold water and low oxygen levels. Lower Wilge (main stem). Seasonal variation is absent due to continuous releases from Katse Dam. Some agricultural runoff (nutrients) in Vaal dam and turbidity.
Suikerbosrand River (upper reaches, before Blesbokspruit confluence)	EWR 9	Agricultural runoff (nutrients and sediments). Instream dams for agricultural water supply – higher water temperatures. Some mining activities – salts.
Suikerbosrand River (after Blesbokspruit confluence)	EWR 10	High salinity from mining and high nutrient concentrations from the Blesbokspruit. Highly impacted.
Blesbokspruit	EWR 11	High salinity due to mine water decants and waste dump diffuse pollution. Occasional high metal values from mines, mine ground water discharges, and industrial discharges. High nutrients due to waste water treatment work discharges, agriculture runoff and informal settlement runoff. Potential for algal growth – rooted macrophytes, filamentous, exotic floating macrophytes (Water hyacinth) and single cell blooms. Diffuse runoff from un - sewered areas leads to seasonally high microbiological contamination.
Mooi River (upper reaches - Klerkskraal Dam to upstream	RE-EWR 2	Fairly good quality water
Klein Vaal	RE-EWR 1	Fairly good quality water. Some impacts detected which include some increase in TDS from origin - could be diffuse impacts originating from coal mines. Witpuntspruit tributary is an issue - acid mine drainage (low pH, high sulphates)

TPCs are also set for physico-chemical parameters for the site, i.e. to monitor deterioration from present state. TPCs are presented as 95th percentiles, i.e. values not to be exceeded more than 5% of the time, for inorganic salts, physical variables and toxics; and 50th percentiles for nutrients, i.e. Total Inorganic Nitrogen (TIN), Soluble Reactive Phosphorous (SRP) or ortho-phosphate and Chlorophyll-*a* (Chl-a). The TPC ranges are defined by the upper boundary of the PES category and 80% thereof for the lower boundary, e.g. if a B category for a PES EcoSpec is < 15 mg/L, the associated TPC would be 12 – 15 mg/L.

Note: Percentiles should be calculated within the framework of the current assessment method (DWAF, 2008b), i.e. using the PES monitoring point as shown on the table for the relevant EWR site, and the most recent 3 to 5 years of data, equivalent to a minimum of 60 data points. Data used from the DWA gauging weir must be requested from the WMS database.

NB: Quality EcoSpecs are therefore related to attaining the water quality category of the overall REC or PES, and are presented as the range that each variable should be in to maintain the required category for that variable. The category specified per variable, and the composition of categories for all variables, will depend on the drivers of water quality per site.

3.3 RIPARIAN VEGETATION

Authored by J Mackenzie. Method developed by J Mackenzie.

The following vegetation components, when assessed together, satisfactorily describe the overall state of any riparian site: exotic invasion, terrestrialisation, general vegetation structure as shown by proportions of riparian woody species, reeds and non-woody species (grasses, sedges and dicotyledonous forbs). Please note the hypotheses on which EcoSpecs (and hence TPCs) are based and that these need to be refined by the DSS once triggered.

3.3.1 Exotic invasion

Ecological specifications were set for the proportion of exotic species invading the riparian zone (Table 3.2). Values were tested by assessing a number of existing sites where exotic aerial cover data were available. Values of perennial exotic species cover (%) in Table 3.2 were used to assess all sites on the Upper Vaal since the percentage cover of exotics is not expected to change for different sites or different systems and is therefore robust enough to transfer across sites.

Table 3.2 Hypothesis on which EcoSpecs for exotic perennial species occurrence in the riparian zone is based

Ecological Class	% Cover (Perennial Exotics)
A	0
A/B	1 - 5
B	5 - 10
B/C	10 - 15
C	15 - 20
C/D	20 - 30
D	30 - 50
D/E	50 - 60
E	60 - 70
E/F	70 - 80
F	> 80

3.3.2 Terrestrialisation

The occurrence of terrestrial species in the riparian zone is not as easily transferrable to different sites and rivers as the exotic vegetation. The sites that have been selected on the Upper Vaal fall into two different biomes: Grasslands (most sites) and Savanna (EWR 4), and some occur close to the Ecotone between the two biomes, but still with predominantly grasslands (EWR 9 and 10). Table 3.3 outlines a hypothesis for EcoSpecs for the occurrence of terrestrial woody species in the riparian zone of sites that occur in the grassland biome (EWR 1, 2, and 3) and Table 3.4 for sites that occur in the Savanna biome.

Table 3.3 Hypothesis for EcoSpecs concerning terrestrialisation of the riparian zone for sites that occur along Highveld Grassland rivers

% Cover (Terrestrial woody species)				
Ecological Class	**Marginal Zone**	**Lower Zone**	**Upper Zone**	**Note**
A	0	0	0 - 5	This hypothesis is based on the phenomenon that terrestrial species occur naturally in the riparian zone (to greater or lesser degrees depending on vegetation biomes), but are reduced in cover and abundance by increased flooding disturbance. Because the focus is on woody species and the sites occur in grassland areas, expected cover is low.
A/B	0	0	5 - 10	
B	0	0	10 - 15	
B/C	0	1 - 5	15 - 20	
C	0	5 - 10	20 - 30	
C/D	0	10 - 15	30 - 40	
D	1 - 5	15 - 20	40 - 50	
D/E	5 - 10	20 - 30	50 - 60	
E	10 - 15	30 - 40	60 - 70	
E/F	15 - 20	40 - 50	70 - 80	
F	> 20	> 50	> 80	

Table 3.4 Hypothesis for EcoSpecs concerning territorialisation of the riparian zone for sites that occur along Highveld Savanna Rivers

% Cover (Terrestrial woody species)				
Ecological Class	**Marginal Zone**	**Lower Zone**	**Upper Zone**	**Note**
A	0	0	0 - 10	Expect the same for Marginal and Lower zones, but the occurrence of terrestrial species in the upper zone will increase due to the species pool in the upland.
A/B	0	0	10 - 20	
B	0	0	20 - 30	
B/C	0	1 - 5	30 - 40	
C	0	5 - 10	40 - 50	
C/D	0	10 - 15	50 - 60	
D	1 - 5	15 - 20	60 - 70	
D/E	5 - 10	20 - 30	70 - 80	
E	10 - 15	30 - 40	80 - 90	
E/F	15 - 20	40 – 50	90	
F	> 20	> 50		

3.3.3 Indigenous Riparian woody cover

The hypothesis for Highveld Grassland Rivers is based on a dynamic whereby natural grazing and fire would maintain predominantly non - woody cover in the riparian zone (Table 3.5). The marginal and lower zone obligate woody species that are expected to occur (*Gomphostigma virgatum* and *Salix mucronata*) are expected in low abundances with low cover since they prefer sites with cobble. Some indigenous, mainly terrestrial woody species, such as *Rhus pyroides* and *Diospyros lycioides* (which are often used to delineate the riparian zone) also occur along the upper zone, especially where there are rocky outcrops, but cover remains low in most areas as expected. As woody cover increases, so the ecological category decreases since the difference from reference conditions is increased. Again, as outlined above, this hypothesis is applicable to river reaches traversing the grassland biome. Sites on the Grassland/Savanna Ecotone or in the Savanna biome will have a different hypothesis (Table 3.6) where increased woody cover would be expected in the reference condition.

Table 3.5 Hypotheses for EcoSpecs concerning indigenous riparian woody cover for sites in the Grassland biome

Highveld Grassland Rivers			
Class	**Marginal Zone**	**Lower Zone**	**Upper Zone**
A	5 - 10	0 - 5	0 - 5
A/B	10 - 20	5 - 10	5 - 10
B	1 - 5; 20 - 30	10 - 15	10 - 15
B/C	30 - 40	15 - 20	15 - 20
C	40 - 50	20 - 30	20 - 25
C/D	0; 50 - 60	30 - 40	25 - 30
D	60 - 70	40 - 50	30 - 40
D/E	70 - 80	50 - 60	40 - 50
E	80 - 90	60 - 70	50 - 60
E/F	> 90	70 - 80	60 - 70
F		> 80	> 70

Table 3.6 Hypotheses for EcoSpecs concerning indigenous riparian woody cover for sites in the Grassland/Savanna Ecotone or Savanna biome

Class	Marginal Zone	Lower Zone	Upper Zone	Note
A	5 - 10	0 - 5	40 - 50	The hypothesis remains the same for marginal and lower zones, but there is an expectation of higher cover in the upper zone, especially *Celtis africana* and *Rhus sp* woodland
A/B	10 - 20	5 - 10		
B	1 - 5; 20 - 30	10 - 15	30 - 40; 50 - 60	
B/C	30 - 40	15 – 20		
C	40 - 50	20 - 30	20 - 30; 60 - 70	
C/D	0; 50 - 60	30 – 40		
D	60 - 70	40 - 50	10 - 20; 70 - 80	
D/E	70 - 80	50 - 60		
E	80 - 90	60 - 70	5 - 10; 80 - 90	
E/F	> 90	70 - 80		
F		> 80	< 5; > 90	

3.3.4 Non - woody indigenous cover (grasses, sedges and dicotyledonous forbs)

Non - woody vegetation is the dominant form of vegetation in Highveld Grassland Rivers, with hydrophilic species such as sedges and some forbs dominating the marginal and lower zones and grasses dominating the upper zone and upland. Hydrophilic grasses such as *Miscanthus junceus* will also cause some mixing in the lower zone. Generally there will be a decrease in the ecological category as non-woody cover is reduced (Table 3.7). The marginal and lower zones will remain robust across sites that occur in the Savanna biome, but the upper zone is likely to have natural reductions as woody species increase.

Table 3.7 Hypotheses for EcoSpecs concerning indigenous non - woody cover

Class	Non - woody Indigenous Cover (grasses, sedges and dicotyledonous forbs)			
	Marginal Zone	Lower Zone	Upper Zone	Note
A	70 - 80	80 - 90	80 - 90	This hypothesis for Highveld Grassland rivers is based on a dynamic whereby grazing and fire maintain a predominantly non-woody cover in the riparian zone. The marginal and lower zones are predominated by sedges and grass species start in the lower zone and dominate the upper zone.
A/B	60 - 70 ; 80 - 90	70 - 80 ; > 90	70 - 80 ; > 90	
B	50 - 60; > 90	60 - 70	50 - 70	
B/C	40 - 50	50 - 60	30 - 50	
C	30 - 40	40 - 50	20 - 30	
C/D	20 - 30	30 - 40	1 - 20	
D	10 - 20	20 - 30	0	
D/E	1 - 10	10 - 20		
E	0	5 - 10		
E/F		1 - 5		
F		0		
A	70 - 80	80 - 90	40 - 50	Hypothesis for Highveld Savanna Rivers: Remains the same for marginal and lower zones but expect reduced non-woody coverage due to expected increased woody cover.
A/B	60 - 70 ; 80 - 90	70 - 80 ; > 90	20 - 30 ; 50 - 60	
B	50 - 60; > 90	60 - 70	10 - 20 ; 60 - 70	

Class	Non - woody Indigenous Cover (grasses, sedges and dicotyledonous forbs)			
	Marginal Zone	Lower Zone	Upper Zone	Note
B/C	40 - 50	50 - 60	1 - 10 ; 70 - 80	
C	30 - 40	40 - 50	0 ; 80 - 90	
C/D	20 - 30	30 - 40	> 90	
D	10 - 20	20 - 30		
D/E	1 - 10	10 - 20		
E	0	5 - 10		
E/F		1 - 5		
F		0		

3.3.5 *Phragmites* species (Reeds) cover

This hypothesis for Highveld Grassland Rivers is based on the predominant absence of *Phragmites australis* in the system, especially in the upper reaches. Farther downstream reed stands may occur in localised patches, but even then should not dominate (Table 3.8).

Table 3.8 Hypotheses for EcoSpecs concerning *Phragmites* (Reed) cover

Class	Marginal Zone	Lower Zone	Upper Zone
A	0	0	0
A/B	0	0	0
B	0	0	0
B/C	0	0	0
C	0	0	0
C/D	1 - 5	1 - 10	0
D	5 - 10	10 - 20	1 - 5
D/E	10 - 15	20 - 30	5 - 10
E	15 - 20	30 - 40	10 - 15
E/F	20 - 25	40 - 50	15 - 20
F	> 25	> 50	> 20

3.4 FISH

Authored: P Kotze and A Deacon

EcoSpec and TPC results are provided in an MS Excel format (Fish EcoSpec and TPCs) for the relevant site, which includes methodology and supporting data and information for future reference, especially during application of TPCs after monitoring. This data will be provided electronically (DWA, 2010a).

The approach for determining EcoSpecs and TPCs is described in sheet 1 of the Excel spreadsheet in a step-wise manner. These steps are listed below (Bold typeface) and further explained below.

Import information from Fish Response Assessment Model (FRAI) model (PES and REC) into relevant sheets (sheet 5 to 10) and follow the instructions at the top of each spreadsheet.

Select indicator taxa for each metric using sheets 7 to 10 and referring to sheet 5 determine whether a species was previously sampled at the relevant EWR site (only use species

known to occur at the site). Use one or two of the highest ranked species (present at site) and list them in Column C (2-EcosSpecsandTPC' worksheet).

The selection of indicator taxa for each metric is done using the 'monitoring indicator' sheet in the Fish Response Assessment Index (FRAI) model for each EWR site/reach. This sheet calculates an indicator value for each species in different variables (such as fast shallow habitats, cover type, etc.) based on the reference Frequency of Occurrence (FROC) and relative intolerance rating of the species. Based on the indicator value determined by the model, species are ranked in order of importance to serve as indicator for a specific variable. The two highest ranked species that are known to occur at the EWR site was generally used as the indicator taxa for the specific metric. If there were uncertainty about the presence of an optimal indicator species (ranked 1 and 2) at a site, or if the species occurred in too low abundance and sampling may therefore be coincidental, these species were excluded and replaced by lower ranked indicator taxa at the site. The two highest ranked indicator species for each metric was used as indicators for reach (automated in Excel spreadsheet) by default.

Describe PES EcoSpecs and TPCs for each metric per site and reach (columns D - G), and EcoSpec for the REC (reach only) (column H). This should be done using the spatial and temporal[2] FROC as well as relative abundance information in the worksheet labeled 5-FROC.

Site versus reach EcoSpec assessment

Fish EcoSpecs and TPCs are described for each fish metric, differentiating between reach and EWR site where applicable. This was done due to the fact that the PES is determined for an entire reach within which the EWR site falls, while fish sampling is however often conducted only at the EWR site, and therefore merits site-specific EcoSpecs and TPCs. EcoSpecs were therefore described for the site to reflect the PES (baseline), while broad EcoSpecs were also given for the reach should detailed monitoring be performed where more than one site is sampled in the reach. EcoSpecs were also described for the reach in terms of the REC (if different from PES), providing a broad description of the expected change in FROC of selected species that would result in the attainment of (improvement towards) the REC.

Once site-specific EcoSpecs were described, TPCs were then derived for each of the selected metrics for the EWR site, giving measurable biotic TPCs for fish as well as conceptual habitat TPC. The habitat TPCs could be quantified once more information becomes available. The biotic (fish) TPCs described for the site should enable the detection of deterioration at the site that may result in a deterioration of the PES towards a lower category. The EcoSpecs described for the reach should provide an indication of conditions when the PES is reaching the REC.

Spatial and temporal FROC of species, as well as their relative abundance (catch per unit effort) were used as units for the different variables or metrics. The calculation of the FROC and relative abundance is based on the results gained during the baseline (generally EWR) surveys, and sometimes also on other available data (important to note that EcoSpecs and TPCs should reflect the PES) and therefore historic data should be used with care in cases where changes could have occurred since the surveys were conducted. The use of data from other sites in a reach must also be applied with circumspection as it may not reflect the species composition and relative

[2] Spatial FROC: presence of fish species at different sites within a reach or in different units/areas at a site (as used in FRAI).
Temporal FROC: Presence of species over time at a specific site (such as EWR site).
Relative abundance/Catch Per Unit Effort (CPUE): Calculated only for electro-fishing in number of individuals/minute (can be done for per site and per species) (if available for many surveys, use lowest observed CPUE to set TPCs).

abundances of the specific EWR site. It is imperative to note that the recommended values given as TPCs should be tested and refined over time as more information becomes available. This is however the best available information at present and should serve as a good starting point. As the monitoring protocol is developed and applied further, these variables should be used to provide specific habitat TPCs in terms of the different fish metrics. Ideally a range of surveys at different base low flows should be conducted, and fish surveys should be done during these surveys. This would be the best applicable way to link the species composition and relative abundances directly and allow for quantification of habitat TPC.

In the "EcoSpecs and TPCs" worksheet rank the metrics in order of most sensitive (rated 1) to less sensitive to detect change (using sheet 6-metric group weights and professional judgement)

Various metrics were selected that would allow the use of fish to determine changes, specifically deterioration in biotic integrity of the aquatic ecosystem. A metric is a measurable component of biological systems, which show an empirical change in value along a gradient of human disturbance (USEPA, 1998). By default, various relevant metrics used in the FRAI model (such as FS habitats, overhanging vegetation, etc.) were selected.

The different metrics were then ranked based on FRAI metric group weighting, relative intolerance or sensitivity of the species to detect change and professional judgement. The purpose of the ranking of metrics is to indicate the metrics most probable (most sensitive) to detecting deterioration. Although different indicator species indicate different changes, the ranking aims to highlight which metrics will be the most sensitive to detect changes at the site.

Complete sheet 3 - Monitoring requirements

Recommendations were also made regarding monitoring requirements taking into consideration the Ecological Importance and Sensitivity metric - rare and endangered and unique fish species at the site. The monitoring recommendations included aspects such as frequency of monitoring, optimal sampling season, location (where and which habitats to focus on) as well as sampling techniques (including recommended effort that should be applied). The monitoring recommendation should also be verified and adapted over time once more information becomes available. It is of critical importance that the follow-up monitoring should be conducted during the same season as when baseline surveys were conducted, or TPCs should be refined for the specific season of the monitoring. The closer the flow (discharge) between monitoring and baseline survey, the more comparable the results and the more likely changes can be detected (it will exclude natural seasonal and habitat differences at the site, which is coupled with natural variation in fish diversity and abundance at the site).

When a TPC for a certain metric is reached, it must first be established whether that specific habitat type (such as SD, water column, overhanging vegetation) has been sampled adequately, to exclude the possibility that the TPC was reached as a result of sampling effort. This would therefore mean that sampling should be done when conditions are optimal. Indicator species can be identified before the actual survey at a site and sampling can then be aimed at specific habitats using the most appropriate sampling method that would give the highest probability of the indicator species being sampled if present. The most preferred sampling method for monitoring purposes is electro-fishing, as this method is very effective in especially flow sensitive habitats (Fast Shallow (FS)) as well as other shallow marginal habitats (such as undercut banks and overhanging

vegetation). This method may also be the most reliable of all methods to calculate relative abundance of a species (CPUE). For the purpose of setting EcoSpecs and TPCs during this study, relative abundance was only determined using electro-fishing data and it was expressed as individuals per minute. Electro-fishing does not however have to be the only sampling method applied during the monitoring phase, as sampling methods should be determined by the indicator species.

Unfortunately due to factors such as cost efficiency, safety at site (presence of crocodiles and hippos) a range of sampling methods can sometimes not be applied. Under such circumstances, the TPCs should be evaluated with caution, considering only those metrics that reflect habitats and species that could be sampled efficiently.

3.5 MACROINVERTEBRATES

Authored: AC Uys

A method to determine EcoSpecs and TPCs for macroinvertebrates was developed during 2006 (DWAF, 2006). As EWRM has never been applied, these methods have not been tested. The method was refined during the Mokolo and Inkomati Reserve studies to cater for additional information collated in terms of habitat via the Rapid Habitat Assessment Method (RHAM) (DWA, 2009b). However the RHAM was not applied during this study and therefore EcoSpecs and TPCs for each site have been estimated on the basis of a set of physical and hydraulic-habitat criteria, a suite of existing data (obtained during the EWR site visits in August – September 2007 and April 2008), and specialist knowledge.

The physical and hydraulic-habitat criteria are considered to be those of relevance to the site's indicator taxa (macroinvertebrate families with a preference for fast-flowing water (Flow Dependant invertebrates - FDI) or marginal vegetation (marginal vegetation invertebrates - MVI)). These criteria include discharge, width, average and maximum depth, average and maximum velocity, substrate type, substrate embeddedness, proportion of different habitat/flow classes across the channel, and algal cover.

It should also be mentioned that no standard method exists for the setting of EcoSpecs and TPCs for macroinvertebrates, and there was thus a requirement to "create" and test a method for this task during the workshop itself. This output is considered preliminary and conservative. Further research and development is required to establish a standard approach to this task.

3.6 MONITORING

Although the development of a monitoring programme was not part of the Terms of Reference, information on geomorphology and fish monitoring is provided in Appendix A and provides valuable information for future planned ecological water resource monitoring.

4 EWR 1: UITKOMS (VAAL RIVER)

A summary of the EcoClassification results are provided below (DWA, 2009c).

4.1 ECOCLASSIFICATION SUMMARY OF EWR 1

EWR 1 Uitkoms (Vaal River)

EIS: HIGH
Presence of rare and endangered *Labeobarbus kimberleyensis* and diversity of habitat.
PES: B/C
Combination of flow and non-flow related impacts. Flow related impacts are mainly due to interbasin transfers (Heysope and Zaaihoek). Mining and agricultural activities in area has caused water quality deterioration and erosion.
REC: B/C
The EIS at EWR 1 is **HIGH** and the PES warrants an improvement. An improvement in the PES EcoStatus would mean that fish and macroinvertebrates must improve from a C to a B EC. No improvement in riparian vegetation is needed as the current EC is an A/B. An improvement in the biotic component EC is dependent on **water quality** changes and not flow related issues. It seems that the water quality at this site is problematic as the fish show signs of serious bacterial infection and quality sensitive macroinvertebrates are absent. Diatoms also indicate that water quality is impaired; however, it is not certain what the water quality problems are. To improve the EC therefore, the water quality problems must be identified to determine how it can be addressed. As no improvement in flow is required, no EWR for the REC will be undertaken.
AEC down 1: C
A hydrological regime with **increased** base flows for longer periods of time in the winter (longer than present transfer) as well as fluctuations in temperature.
AEC down 2: C
A hydrological regime with **decreased** base flows below natural (no transfers) with potential for some low flows.
Decreased moderate floods.
Deteriorated water quality due to increased impacts of mining.

Driver Components	PES and REC Category	Trend	AEC↓1	AEC↓2
HYDROLOGY	C			
WATER QUALITY	C	Stable	C	C
GEOMORPHOLOGY	B/C	Negative	C	C
Response Components	**PES Category**	**Trend**	**AEC↓1**	**AEC↓2**
FISH	C (B)	Negative	D	D
MACRO INVERTEBRATES	C (B)	Stable	C	D
INSTREAM	C		C	D
RIPARIAN VEGETATION	A/B	Stable	B/C	B/C
ECOSTATUS	B/C (B)		C	C

Note: Categories in red relates to a REC based on water quality improvements.

EcoSpecs and TPCs for EWR 1 are provided for the different components in Section 4.2 to 4.7.

4.2 GEOMORPHOLOGY

EcoSpecs and TPCs based on the GAI are provided in Section 4.2.1.

4.2.1 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Descriptor	EcoSpec	TPC
Bed material composition	Maintaining bed composition, thus maintaining the physical habitat diversity. Fining of the bed (i.e. decreases in the size of the 16th, 50th and 84th percentiles of the sediment size distribution as indicated to the left) would indicate insufficient flows at the site to maintain the geomorphological condition. Coarsening of the bed (increasing the sediment sizes) would indicate further elevated flows, bed-armouring and loss of fine-sediment habitat types.	
	D_{16} = 2 mm	D_{16} sediment size must be between 1 – 4 mm
	D_{50} = 30 mm	D_{50} sediment size must be between 20 – 40 mm
	D_{84} = 250 mm	D_{84} sediment size must be between 200 – 300 mm
Channel morphology	Maintain the channel form and associated processes and habitats. At this site, wetlands (pools) are located in the bed of a seasonal channel at the site. The permanent nature of these pools appears to be unique in the reach. The elevated base flows due to inter-basin transfers has caused incision of the active channel, probably reducing the frequency of floodplain inundation which would be particularly negative for the floodplain sections located approx 20 km upstream of the site. Additionally, the absence of bars and islands in the reach also a likely result of erosion from elevated base flows. To maintain the PES, no further channel incision can occur.	
		Any deepening of the channel at cross section scale

4.3 PHYSICO-CHEMICAL VARIABLES

EcoSpecs and TPCs are provided in Section 4.3.1 – 4.3.2.

4.3.1 EcoSpecs relating to physico-chemical data: PES and REC

River: Vaal		EWR: 1
Water quality metrics		**EcoSpecs: PES and REC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be ≤ 37 mg/L.
	Na_2SO_4	The 95th percentile of the data must be ≤ 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be ≤ 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be ≤ 21 mg/L.
	NaCl	The 95th percentile of the data must be ≤ 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be ≤ 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be ≤ 30 mS/m.
	pH	The 5th and 95th percentiles of the data must range from 5.9 to 8.8.
	Temperature	Small deviation from the natural temperature range.
	Dissolved oxygen	The 5th percentile of the data must be ≥ 7.5 mg/L.
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
Nutrients	TIN	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
	PO_4-P	The 50th percentile of the data must be ≤ 0.25 mg/L.
Response variables	Chl-a phytoplankton	The 50th percentile of the data must be ≤ 0.015 mg/L.
	Chl-a periphyton	The 50th percentile of the data must be < 10 µg/L.
	Toxics	The 50th percentile of the data must be ≤ 21 mg/m^2.

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected

4.3.2 TPCs relating to physico-chemical data

River: Vaal VS4 GDDC11 Vaal River at R35 Bloukop bridge		EWR: 1
Water quality metrics		**TPC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be 28 – 37 mg/L.
	Na_2SO_4	The 95th percentile of the data must be 16 – 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be 12 – 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be 17 – 21 mg/L.
	NaCl	The 95th percentile of the data must be 36 – 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be 280 – 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be < 30 mS/m.
	pH	The 5th and 95th percentiles of the data must be < 6.7 and > 7.8.
	Temperature	Initiate baseline monitoring for this variable.
	Dissolved oxygen	The 5th percentile of the data must be 7.8 – 7.5 mg/L.
Nutrients	TIN	The 50th percentile of the data must be 0.2 – 0.25 mg/L.
	PO_4-P	The 50th percentile of the data must be 0.012 – 0.015 mg/L.
Response variables	Chl-a phytoplankton	The 50th percentile of the data must be 8 – 10 µg/L.
	Chl-a periphyton	The 50th percentile of the data must be 17 – 21 mg/m^2.
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

Data for EWR 1 is low confidence due to poor data records. Although ecological specifications are provided per metric for EWR 1 the resolution is low. Monitoring would therefore be essential to improve the database and assess the conditions. Due to the relatively good water quality at this

site (a small amount of available data), biotic responses such as reported fish kills are probably driven by other drivers such as flow changes (which may result in a concomitant change in physico-chemistry). The water quality is changed at this site due to interbasin transfer from the Usutu River to the Perdewaterspruit which also raise the base flow from April to October. The increasing trend in TDS could be due to diffuse impacts originating from coal mines. If coal mining continues and not managed, the Witpuntspruit tributary could become an issue in terms of acid mine drainage (low pH, high sulphates) which would impact negatively on this site.

4.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the VEGRAI data are provided Section 4.4.1 to 4.4.2. Section 4.4.2 is a summary of Section 4.4.1 and is explained below and applies to all the riparian vegetation sections in this report:

- In Section 4.4.1 the EcoSpecs, TPCs and baseline information of the assessment component and associated vegetation zone has been assigned a number, e.g. Perennial exotics in the marginal and lower zone = 1; Terrestrial woody species cover in the lower zone = 2.
- In Section 4.4.2 a green block marked 1 under the perennial exotic column for instance refers to maintaining the exotics cover <5% (EcoSpec) which has been assigned the number 1 and coloured green in the table under Section 4.4.1.
- Colour coding in the table below and in Section 4.4.2 refers to:
  - EcoSpec: Green
  - TPC: Red
  - Baseline: Blue
  - PES and REC: Orange

4.4.1 EcoSpec and TPC description relating to VEGRAI monitoring data: PES and REC

PES and REC	Assessed Component	Zone Assessed	EcoSpec (PES)		TPC (PES)		EcoSpec (REC)	Baseline Note	
A/B	Exotic Invasion (perennial exotics).	Marginal and Lower zones.	Maintain perennial exotic species cover < 5%.	1	An increase in perennial exotic species above 5%.	1	Same as PES.	VEGRAI recorded < 10% on all zones, but perennial exotics occurred mainly in the marginal and lower zones.	1
	Terrestrial woody species cover.	Lower zone.	Maintain the absence of terrestrial woody species.	2	A presence of terrestrial woody species.	2		Grassland dominated system, with little record of terrestrial woody cover: terrestrials were restricted to rocky outcrops, mainly in the upper zone.	2
		Upper zone.	Maintain terrestrial woody species cover below 10%.	3	An increase in terrestrial woody species above 10%.	3			3
	Indigenous Riparian Woody Cover.	Marginal zone.	Maintain indigenous riparian woody cover below 20%, but retain presence i.e. not 0%.	4	An absence of riparian woody cover OR an increase above 10%.	4		VEGRAI recorded < 10%, *Gomphostigma virgatum* mainly.	4
		Lower zone.	Maintain indigenous riparian woody cover below 10%.	5	An increase in riparian woody cover above 10%.	5		VEGRAI recorded < 10%, *Rhus pyroides* and *Diospyros lycioides* mainly.	5
		Upper zone.	Maintain indigenous riparian woody cover below 10%.	6	An increase in riparian woody cover above 10%.	6		VEGRAI recorded < 10%, *Diospyros lycioides* mainly.	6
	Non-woody	Marginal	Maintain non-	7	A decrease in non-	7		VEGRAI recorded >	7

PES and REC	Assessed Component	Zone Assessed	EcoSpec (PES)		TPC (PES)		EcoSpec (REC)	Baseline Note	
	Indigenous Cover (grasses, sedges and dicotyledonous forbs).	zone.	woody cover between 60 and 90%, with sedges (*Cyperus sp* predominating.		woody cover below 70% OR and increase above 90% OR a change in species composition so that sedges (*Cyperus sp* are no longer dominant.			80%; *Cyperus marginatus* markedly dominant.	
		Lower and Upper zones.	Maintain non-woody cover above 70%, with grasses predominating.	8	A decrease in non-woody cover below 80%.	8		VEGRAI recorded > 80%; mixture of sedges and grasses (notably *Miscanthus* and terrestrial grasses).	8
	Phragmites (reed) cover.	Riparian zone.	Maintain the absence of reeds.	9	A presence of reeds.	9		Reeds were not observed at the site, and are not expected.	9

4.4.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data

This section is a summary of the Table provided in Section 4.4.1.

Colour coding in the table below refers to:

EcoSpecs	TPC	Baseline	PES and REC

Class	Perennial Exotics (%)			Terrestrialization (%)			Riparian Woody (%)			Non-woody (%)			Reeds (%)
Marginal Zone													
A	1	0	1		0		4	5 - 10	4	7	70 - 80	7	9	0
A/B	1	1 - 5	1		0		4	10 - 20	4	7	60 - 70; 80 - 90	7	9	0
B		5 – 10			0		4	1 - 5; 20 - 30			50 - 60; >90	7	9	0
B/C		10 - 15			0			30 - 40			40 - 50		9	0
C		15 - 20			0			40 - 50			30 - 40		9	0
C/D		20 - 30			0			0; 50 - 60			20 - 30			1 - 5
D		30 - 50			1 - 5			60 - 70			10 - 20			5 - 10
D/E		50 - 60			5 - 10			70 - 80			1 - 10			10 - 15
E		60 - 70			10 - 15			80 - 90			0			15 - 20
E/F		70 - 80			15 - 20			>90						20 - 25
F		>80			>20									>25
Lower Zone														
A	1	0	1	2	0	2	5	0 - 5	5	8	80 - 90	8	9	0
A/B	1	1 - 5	1	2	0	2	5	5 - 10	5	8	70 - 80; >90	8	9	0
B		5 – 10		2	0	2		10 - 15			60 - 70		9	0
B/C		10 - 15			1 – 5			15 - 20			50 - 60		9	0
C		15 - 20			5 - 10			20 - 30			40 - 50		9	0
C/D		20 - 30			10 - 15			30 - 40			30 - 40			1 - 10
D		30 - 50			15 - 20			40 - 50			20 - 30			10 - 20
D/E		50 - 60			20 - 30			50 - 60			10 - 20			20 - 30
E		60 - 70			30 - 40			60 - 70			5 - 10			30 - 40
E/F		70 - 80			40 - 50			70 - 80			1 - 5			40 - 50
F		>80			>50			>80						>50
Upper Zone														
A		0	1	3	0 - 5	3	6	0 - 5	6	8	80 - 90	8	9	0
A/B		1 - 5	1	3	5 - 10		6	5 - 10	6	8	70 - 80; >90	8	9	0
B		5 - 10			10 - 15			10 - 15			50 - 70		9	0
B/C		10 - 15			15 - 20			15 - 20			30 - 50		9	0
C		15 - 20			20 - 30			20 - 25			20 - 30		9	0
C/D		20 - 30			30 - 40			25 - 30			1 - 20		9	0
D		30 - 50			40 - 50			30 - 40			0			1 - 5
D/E		50 - 60			50 - 60			40 - 50						5 - 10
E		60 - 70			60 - 70			50 - 60						10 - 15
E/F		70 - 80			70 - 80			60 - 70						15 - 20
F		>80			>80			>70						>20

4.5 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 4.5.1. The spatial FROC of EWR 1 is provided in Section 4.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

4.5.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES/REC						REC
			EWR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
4	Species richness.	All indigenous species.	Five expected indigenous fish species to be sampled (as per EWR baseline survey).	Less than four fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity - depth categories and cover features (to be quantified by RHAM if applicable).	All indigenous species.		Baseline (PES) FRAI score of 71% (C) calculated for the reach. Any decreased FROC in reach of especially ASCL, BAEN and LCAP (refer to FROC: Table 2[1]) OR FRAI scores decreasing below 62.02% (category C/D).	N/A, PES same as REC (improvement can only be reached through water quality improvement).
3	Relative abundance (overall).	All indigenous species.	Fish sampled at > 0.4 individuals per minute (electrofishing).	Relative abundance of less than 0.3 individual per minute sampled at the site (during same season as baseline data) when habitat can be sampled efficiently using electrofishing.	N/A	N/A		N/A	
5	Alien fish species.	Any alien/introduced spp.	0ne alien fish species (MSAL) sampled at site during 50% of the time at a relative abundance of 0.01 indiv/min^2. (Another 2 species, namely CCAR and MSAL known to be present in reach).	Increase in the number of alien species (> 3 species during any survey) OR increased relative abundance of MSAL of > 0.05 indiv/min.	N/A	Any alien/introduced spp.		MSAL, CCAR and GAFF are known to be present in the reach. Increase in the number of alien species (> 3 species in reach)/presence of any other alien species than MSAL, CCAR and GAFF.	
1	FD and FS habitats, substrate, flow dependant spp (flow alteration), water quality intolerance, water column.	BAEN, LCAP.	BAEN and LCAP sampled 100% of time. BAEN present at relative abundance of > 0.1 indiv/min. and LCAP sampled at relative abundance of > 0.25 indiv/min.	BAEN and LCAP present less than 100% of time (not sampled during any survey) AND/OR decrease in relative abundance of < 0.1 indiv/min for BAEN and < 0.2 indiv/min for LCAP.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows), Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates. Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools), Reduction in suitability of water column (i.e. increased sedimentation of pools).	BAEN	LCAP	Any decreased FROC in reach of BAEN and LCAP (refer to FROC, column F: Table 2).	
1	Water quality intolerance.	BAEN, LCAP.	BAEN and LCAP sampled 100% and present at relative abundance of > 0.1 indiv/min. and LCAP sampled at relative abundance of > 0.25 indiv/min.	BAEN and LCAP present less than 100% of time (not sampled during any survey) AND/OR decrease in relative abundance of < 0.1 indiv/min for BAEN and < 0.2 indiv/min for LCAP.	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	BKIM	LCAP	Any decreased FROC in reach of BKIM and LCAP (refer to FROC, column F: Table 2).	

Rank	Metric	Indicator spp.	PES/REC						REC
			EWR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
2	FS habitats.	BAEN, ASCL.	BAEN and ASCL sampled 100% of time. BAEN present at relative abundance of > 0.1 indiv/min. and ASCL sampled at relative abundance of > 0.007 indiv/min.	BAEN present less than 100% of time (not sampled during any survey) AND/OR ASCL absent during 2 consecutive surveys AND/OR decrease in relative abundance of < 0.1 indiv/min for BAEN.	Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows).	BAEN	ASCL	Any decreased FROC in reach of BAEN and ASCL (refer to FROC, column F: Table 2).	
6	SS habitats.	CGAR.	CGAR present (50% of surveys) at relative abundance of 0.03 indiv/min electrofishing.	CGAR absent during two consecutive surveys.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).	BANO	PPHI	Any decreased FROC in reach of BANO and PPHI (refer to FROC, column F: Table 2).	
8	Overhanging vegetation.	No indicator species sampled at site during baseline surveys. Could be included in future if/when sampled.	Significant change in overhanging vegetation habitats.			PPHI	BPAU	Any decreased FROC in reach of PPHI and BPAU (refer to FROC, column F: Table 2).	
2	Undercut banks.	ASCL.	ASCL sampled 100% of time at relative abundance of > 0.007 indiv/min.	ASCL absent during 2 consecutive surveys.	Significant change in undercut bank habitats.	ASCL	PPHI	Any decreased FROC in reach of ASCL and PPHI (refer to FROC, column F: Table 2).	
7	Instream vegetation.	No indicator species sampled at site during baseline surveys. Could be included in future if/when sampled.	Significant change in instream vegetation habitats.			BPAU	BANO	Any decreased FROC in reach of BPAU and BANO (refer to FROC, column F: Table 2).	

1 Refer to electronic data (DWA, 2010a). 2 Individual (s)/per minute

4.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (C)		REC (C)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
ASCL	***Austroglanis sclateri* (Boulenger, 1901)**	**2**	**2**	**1**	**Same as PES**
BAEN	***Labeobarbus aeneus* (Burchell, 1822)**	**4**	**4**	**3**	
BANO	*Barbus anoplus* (Weber, 1897)	2	1	0	
BPAU	*Barbus paludinosus* (Peters, 1852)	2	1	0	
BKIM	*Labeobarbus kimberleyensis* (Gilchrist and Thompson, 1913)	2	1	0	
CGAR	***Clarias gariepinus* (Burchell, 1822)**	**2**	**2**	**1**	
LCAP	***Labeo capensis* (Smith, 1841)**	**4**	**4**	**3**	
LUMB	***Labeo umbratus* (Smith, 1841)**	**3**	**3**	**2**	
PPHI	*Pseudocrenilabrus philander* (Weber, 1897)	2	1	0	
(species in bold sampled at EWR site during baseline surveys)					

4.6 MACROINVERTEBRATES

4.6.1 Reference Conditions

Reference conditions for macroinvertebrates are based on professional judgment and data collected by Dr Mark Chutter from his Sites 2A and 3 (Chutter, 1967: Table 11). The reference SASS5 Score is 176 and the ASPT is 6.3.

4.6.2 Baseline Description

Baseline biomonitoring data available for EWR 1 are summarised as follows:

Date	SASS5[1] Score	ASPT[2]	No. of Taxa	Category (Dallas 2007)	MIRAI[3] (%)	PES
07 - 04 - 08	104	5.8	18	C	74.6%	C
21 - 09 - 07	89	5.2	17	D		

1 South African Scoring System version 5 2 Average Score Per Taxon
3 Macroinvertebrate Response Assessment Index

4.6.3 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration, were recorded at the site during baseline sampling, and were selected as monitoring indicators for EWR 1.

Family	Flow				Substrate				Water Quality			
	Standing (<0.1 m/s)	Slow (0.1 - 0.3 m/s)	Mod (0.3 - 0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Vegetation	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7 - 10)	Low (SASS 4 - 6)
Baetidae (>2 spp)	●	●	⬤	⬤	●	●	⬤	●	●		10	
Leptophlebiidae (Prongills)	●	⬤	●		●	●	⬤	●	⬤		9	
Tricorythidae (Stout crawlers)			●	⬤	●	⬤	⬤	●			9	
Atyidae (Freshwater shrimps)		●						⬤			8	
Elmiidae (Riffle beetles)			●	⬤		⬤	●	●			8	
Hydropsychidae (2 spp)			●	⬤	●	⬤	●					5
Hydropsychidae (>2 spp)			●	⬤	●	⬤	●			12		
Perlidae (Stoneflies)			●	⬤		●	⬤			12		
Psephenidae (Water pennies)			●	⬤		⬤	●				10	
Athericidae		●	⬤			●	⬤	●			10	
Caenidae (Squaregills)	●	⬤				●	⬤	●	●			6
Dytiscidae (Diving beetles)	⬤	●						⬤				5

● = Partial Preference ⬤ = Strong Preference

Caddisflies recorded at the site during baseline sampling included *Cheumatopsyche thomasseti, C. afra, Amphipysche scottae* and *Macrostenum capense.* The presence of stoneflies (Perlidae) was confirmed by a single empty shuck only.

4.6.4 EcoSpecs and TPCs relating to the MIRAI data: PES and REC

EcoSpecs and TPCs for the PES (C) at EWR 1 are provided below.

ECOSPECS: Biota	TPCs
SASS5 Score between 90 and 130.	SASS5 Score < 100.
ASPT between 5.3 and 6.1.	ASPT < 5.5.
MIRAI Score between 62% and 77%.	MIRAI Score < 64%.
To ensure that no group consistently dominates the fauna, defined as C abundance (> 100) over two consecutive surveys.	Any taxon abundance 'D' (> 1000) in two consecutive surveys.
Baetidae > 2 spp.	Baetidae < 2 spp.
Tricorythidae present (except winter).	Tricorythidae absent from two or more consecutive surveys (except winter).
Atyidae present.	Atyidae absent on two or more consecutive surveys.
Elmiidae present.	Elmiidae absent on two or more consecutive surveys.
Hydropsychidae > 1 spp.	Hydropsychidae < 1 spp.
Simuliidae present.	Simuliidae absent on two or more consecutive surveys.

5 EWR 2: GROOTDRAAI (VAAL RIVER)

A summary of the EcoClassification results are provided below (DWA, 2009c).

5.1 ECOCLASSIFICATION SUMMARY OF EWR 2

EWR 2 Grootdraai (Vaal River)

EIS: MODERATE
PES: C
Combination of flow and non - flow related impacts. Impacts mostly related to changes in flow regime due to Grootdraai Dam.
REC: C
Maintain the PES due to the **MODERATE** EIS rating. However note that there is rare and endangered *Labeobarbus kimberleyensis* present which warrants improvement of the fish EC.

AEC up: B
This ecological scenario is important due to the presence of *L. kimberleyensis*.
Change in the operation of Grootdraai Dam, which includes the release of flows (base flows) with more natural seasonal patterns and the release of moderate floods to remove fines and no bottom releases.
AEC down: C/D
Less spilling (i.e. fewer floods) and decreased base flows.
Increased bottom releases.

Driver Components	PES and REC Category	Trend	AEC↑	AEC↓
HYDROLOGY	D			
WATER QUALITY	B/C	Negative	B	B/C
GEOMORPHOLOGY	D	Stable	D	D/E
Response Components	**PES Category**	**Trend**	**AEC↑**	**AEC↓**
FISH	C	Stable	B	D
MACRO INVERTEBRATES	C	Stable	B/C	C/D
INSTREAM	C		B/C	C/D
RIPARIAN VEGETATION	B/C	Stable	B	C
ECOSTATUS	C		B	C/D

EcoSpecs and TPCs for EWR 2 are provided for the different components in Section 5.2 to 5.7.

5.2 GEOMORPHOLOGY

EcoSpecs and TPCs relating to GAI monitoring data: PES and REC.

5.2.1 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Descriptor	EcoSpec	TPC
Bed material composition	Sampling of the dry season bed material at the EWR site (using a sample size of not less than 500 points) should be undertaken at the prescribed intervals (every 5 years) to assess impacts of flow on the bed sediment and therefore as an indication of the change of available habitat for instream biota. Bottom releases appear to be introducing a substantial fines component whilst the coarse material is trapped in the dam, so fining of the bed (i.e. decreases in the size of the 16th, 50th and 84th percentiles of the sediment size distribution as indicated to the left) will be undesirable from an instream habitat perspective.	
	D_{16} = 10 mm	D_{16} sediment size must be greater than 5 mm
	D_{50} = 80 mm	D_{50} sediment size must be greater than 50 mm
	D_{84} = 150 mm	D_{84} sediment size must be greater than 100 mm
Channel morphology	At this site, Reference condition had fewer cut banks (the site is located immediately below Grootdraai Dam). To maintain the PES, no further channel incision can occur. Incised channels overtop less frequently and cause desiccation of the upper riparian and floodplain areas. Incision can be monitored through resurveyed cross - sections.	
		Any deepening of the channel at cross section scale.

5.3 PHYSICO - CHEMICAL VARIABLES

TPCs and EcoSpecs are provided in Section 5.3.1 – 5.3.2.

5.3.1 EcoSpecs relating to physico - chemical data: PES and REC

River: Vaal		EWR 2
Water quality metrics		**EcoSpec: PES and REC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be ≤ 37 mg/L.
	Na_2SO_4	The 95th percentile of the data must be ≤ 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be ≤ 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be ≤ 21 mg/L.
	NaCl	The 95th percentile of the data must be ≤ 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be ≤ 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be ≤ 30 mS/m.
	pH	The 5th and 95th percentiles of the data must range from 6.5 to 8.8.
	Temperature	Small deviation from the natural temperature range.
	Dissolved oxygen	The 5th percentile of the data must be ≥ 7.5 mg/L.
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
Nutrients	TIN	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
	PO_4 - P	The 50th percentile of the data must be ≤ 0.25 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be ≤ 0.015 mg/L.
	Chl - a periphyton	The 50th percentile of the data must be <10 µg/L.
	Toxics	The 50th percentile of the data must be ≤ 21 mg/m^2.

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

5.3.2 TPCs relating to physico - chemical data

River: Vaal		EWR :2 Vaal - Grootdraai
Water quality metrics		**TPC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be 28 – 37 mg/L.
	Na_2SO_4	The 95th percentile of the data must be 16 – 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be 12 – 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be 17 – 21 mg/L.
	NaCl	The 95th percentile of the data must be 36 – 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be 280 – 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be < 30 mS/m.
	pH	The 5th and 95th percentiles of the data must be < 6.7 and > 7.8.
	Temperature	Initiate baseline monitoring for this variable.
	Dissolved oxygen	The 5th percentile of the data must be 7.8 – 7.5 mg/L.
Nutrients	TIN	The 50th percentile of the data must be 0.2 – 0.25 mg/L.
	PO_4 - P	The 50th percentile of the data must be 0.012 – 0.015 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be 8 – 10 µg/L.
	Chl - a periphyton	The 50th percentile of the data must be 17 – 21 mg/m^2.
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

Major water quality related impacts at EWR 2 are due to heating of water from Grootdraai Dam. There are some man-made modifications in the catchment but there are no known problems or concerns regarding DO, as most oxygen sensitive species are present. Silt is captured in the Grootdraai Dam. However, if greater flows are released the following water quality changes would occur; greater dissolved oxygen, temperatures that are closer to natural. Greater flows could also

have a detrimental impact as the buffering capacity of the dam could be reduced and the poorer water quality from the Blesbokspruit and Leeuspruit could impact on this EWR site. To improve water quality, downstream mixed releases (bottom and top water for increased oxygen and realistic temperatures), with natural seasonal patterns are needed.

5.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the VEGRAI data are provided Section 5.4.1 to 5.4.2.

5.4.1 EcoSpec and TPC description relating to VEGRAI monitoring data: PES and REC

PES and REC	Assessed Component	Zone Assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Baseline Note
B/C	Exotic Invasion (perennial exotics)	Marginal and Lower zones	Maintain perennial exotic species cover < 15%.	The presence of exotic perennial species.	Same as PES	> 10% recorded during VEGRAI assessment but all exotics were non - woody annual weeds: no perennial exotic species were recorded.
		Upper zone	Maintain perennial exotic species cover < 15%.	An increase in perennial exotic species above 5%.		> 10% recorded during VEGRAI assessment with about 5% being perennial exotics (*Salix babylonica, Moris alba*).
	Terrestrial woody species cover	Marginal zone	Maintain the absence of terrestrial woody species.	The presence of terrestrial woody species.		No woody terrestrial species were recorded in the marginal and lower zones, and *Diospyros lycioides* comprised < 10% cover in the upper zone.
		Lower zone	Maintain cover of terrestrial woody species below 5%.	The presence of terrestrial woody species.		
		Upper zone	Maintain cover of terrestrial woody species below 20%.	An increase in woody terrestrial species cover above 10%.		
	Indigenous Riparian Woody Cover	Marginal zone	Maintain indigenous riparian woody cover below 40%, but retain presence i.e. not 0%.	A decrease in riparian woody cover below 5% OR an increase above 20%.		< 10% recorded Gomphostigma virgatum the only species.
		Lower zone	Maintain indigenous riparian woody cover below 20%.	An increase in riparian woody cover above 10%.		0% recorded.
		Upper zone	Maintain indigenous riparian woody cover below 20%.	An increase in riparian woody cover above 10%.		< 10% recorded, *Diospyros lycioides* the only indigenous species.
	Non - woody Indigenous Cover (grasses, sedges and dicotyledonous forbs)	Marginal zone	Maintain non - woody cover above 40%, with sedges predominating.	A decrease in non - woody cover below 60%.		80 - 100% recorded during VEGRAI assessment.
		Lower zone	Maintain non - woody cover above 50%, with sedges predominating.	A decrease in non - woody cover below 70%.		80 - 100% recorded during VEGRAI assessment.
		Upper zone	Maintain non - woody cover above 30%, with grasses predominating.	A decrease in non - woody cover below 50%.		60 - 80% recorded during VEGRAI assessment.
	Phragmites (reed) cover	Riparian zone	Maintain the absence of reeds.	A presence of reeds.		< 5% reeds recorded in the marginal zone during VEGRAI assessment, not recorded on other zones, but also not expected to occur.

5.4.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data

Colour coding in the table below refers to:

EcoSpecs	TPC	Baseline	PES and REC

Class	Perennial Exotics (%)	Terrestrialization (%)	Riparian Woody (%)	Non-woody (%)	Reeds (%)
Marginal Zone					
A	0	0	5 - 10	70 - 80	0
A/B	1 - 5	0	10 - 20	60 - 70; 80 - 90	0
B	5 - 10	0	1 - 5 ; 20 - 30	50 - 60; >90	0
B/C	10 - 15	0	30 - 40	40 - 50	0
C	15 - 20	0	40 - 50	30 - 40	0
C/D	20 - 30	0	0 ; 50 - 60	20 - 30	1 - 5
D	30 - 50	1 - 5	60 - 70	10 - 20	5 - 10
D/E	50 - 60	5 - 10	70 - 80	1 - 10	10 - 15
E	60 - 70	10 - 15	80 - 90	0	15 - 20
E/F	70 - 80	15 - 20	>90		20 - 25
F	>80	>20			>25
Lower Zone					
A	0	0	0 - 5	80 - 90	0
A/B	1 - 5	0	5 - 10	70 - 80; >90	0
B	5 - 10	0	10 - 15	60 - 70	0
B/C	10 - 15	1 - 5	15 - 20	50 - 60	0
C	15 - 20	5 - 10	20 - 30	40 - 50	0
C/D	20 - 30	10 - 15	30 - 40	30 - 40	1 - 10
D	30 - 50	15 - 20	40 - 50	20 - 30	10 - 20
D/E	50 - 60	20 - 30	50 - 60	10 - 20	20 - 30
E	60 - 70	30 - 40	60 - 70	5 - 10	30 - 40
E/F	70 - 80	40 - 50	70 - 80	1 - 5	40 - 50
F	>80	>50	>80		>50
Upper Zone					
A	0	0 - 5	0 - 5	80 - 90	0
A/B	1 - 5	5 - 10	5 - 10	70 - 80; >90	0
B	5 - 10	10 - 15	10 - 15	50 - 70	0
B/C	10 - 15	15 - 20	15 - 20	30 - 50	0
C	15 - 20	20 - 30	20 - 25	20 - 30	0
C/D	20 - 30	30 - 40	25 - 30	1 - 20	0
D	30 - 50	40 - 50	30 - 40	0	1 - 5
D/E	50 - 60	50 - 60	40 - 50		5 - 10
E	60 - 70	60 - 70	50 - 60		10 - 15
E/F	70 - 80	70 - 80	60 - 70		15 - 20
F	>80	>80	>70		>20

5.5 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 5.5.1. The spatial FROC of EWR 2 is provided in Section 5.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

5.5.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES/REC						AEC↑
			EWR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
5	Species richness.	All indigenous species.	Nine expected indigenous fish sp to be sampled (as per EWR baseline survey).	Less than six species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity - depth categories and cover features (to be quantified by RHAM if applicable).	All indigenous species.		Baseline (PES) FRAI score of 73.1% (C) calculated for the reach. Any decreased FROC in reach of especially ASCL, BAEN and LCAP (refer to FROC: Table 2[1]) OR FRAI scores decreasing below 62. 02% (category C/D).	An improvement from PES FROC in the reach for especially BANO, BKIM and LCAP should be indicative of reaching/maintaining the improved AEC (refer to FROC sheet for more detail).
4	Relative abundance.	All indigenous species.	Fish sampled at > 0.6 individuals per minute (electrofishing).	Relative abundance of less than 0.5 individual per minute sampled at the site (during same season as baseline data) when habitat can be sampled efficiently using electrofishing.	N/A	N/A		N/A	
10	Alien fish species.	Any alien/introduced spp.	Two alien fish species (MSAL and CCAR) sampled at site during 100% at a relative abundance of < 0.013 indiv/min for MSAL and < 0.034 indiv/min for CCAR.	Increase in the number of alien species (> 2 species during any survey) **OR** increased relative abundance of MSAL of > 0.03 indiv/min and CCAR > 0.05 indiv/min.	N/A	Any alien/introduced spp.		Increase in the number of alien species (> 2 species in reach) OR presence of any alien species other than MSAL, and CCAR.	
1	FD habitats, substrate, flow dependant spp (flow alteration), SD habitats, water column.	BAEN, LCAP	BAEN and LCAP sampled 100% of time. BAEN present at relative abundance of > 0.18 indiv/min. and LCAP sampled at relative abundance of > 0.02 indiv/min.	BAEN and LCAP present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.1 indiv/min for BAEN and < 0.01 indiv/min for LCAP.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates, increased zero flows, Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools), Reduction in suitability of water column (i.e. increased sedimentation of pools). To be quantified with RHAM.	BAEN	LCAP	Any decreased FROC in reach of BAEN and LCAP (refer to FROC, column F: Table 2).	
2	FS habitats.	BAEN, BKIM	BAEN sampled 100% of time and BKIM 50% of time. BAEN present at relative abundance of > 0.18 indiv/min. and BKIM sampled at relative abundance of 0.02 indiv/min.	BAEN present less than 100% of time (not sampled during any survey) or BKIM present less than 5% of time (absent during 2 consecutive surveys) **AND/OR** decrease in relative abundance of < 0.01 indiv/min for BAEN.	Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows). To be quantified with RHAM.	BAEN	BKIM	Any decreased FROC in reach of BAEN and BKIM (refer to FROC, column F: Table 2).	

Rank	Metric	Indicator spp.	PES/REC						AEC↑
			EWR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
3	Water quality intolerance.	BKIM, LCAP	LCAP sampled 100% and BKIM 50% of time. BAEN present at relative abundance of > 0.18 indiv/min and BKIM sampled at relative abundance of 0.02 indiv/min.	LCAP present less than 100% of time (not sampled during any survey) or BKIM present less than 50% of time (absent during 2 consecutive surveys) **AND/OR** decrease in relative abundance of < 0.1 indiv/min.	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	BKIM	LCAP	Any decreased FROC in reach of BKIM and LCAP (refer to FROC, column F: Table 2).	
9	SS habitats.	PPHI, CGAR	CGAR sampled 100% and PPHI 50% of time. CGAR present at relative abundance of > 0.006 indiv/min. and PPHI sampled at relative abundance of 0.04 indiv/min.	CGAR **AND** PPHI present less than 50% of time (absent during 2 consecutive surveys).	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats). To be quantified with RHAM.	PPHI	CGAR	Any decreased FROC in reach of PPHI and CGAR (refer to FROC, column F: Table 2).	
8	Overhanging vegetation.	PPHI, BPAU	BPAU sampled 100% and PPHI 50% of time. BPAU was present at relative abundance of > 0.25 indiv/min. and PPHI sampled at relative abundance of 0.04 indiv/min.	BPAU present less than 100% (absent during any survey) or present at relative abundance < 0.2 indiv/min. **AND/OR** PPHI present less than 50% of time (absent during 2 consecutive surveys).	Significant change in overhanging vegetation habitats (to be quantified with RHAM).	PPHI	TSPA	Any decreased FROC in reach of PPHI and TSPA (refer to FROC, column F: Table 2).	
7	Undercut banks.	PPHI, ASCL	PPHI and ASCL sampled 50% of time. ASCL present at relative abundance of > 0.03 indiv/min. and PPHI sampled at relative abundance of 0.04 indiv/min.	PPHI **AND/OR** ASCL present less than 50% of time (absent during 2 consecutive surveys).	Significant change in undercut bank habitats (to be quantified with RHAM).	PPHI	ASCL	Any decreased FROC in reach of PPHI and ASCL (refer to FROC, column F: Table 2).	
6	Instream vegetation.	BPAU, BANO	BPAU sampled 100% and BANO 50% of time. BPAU present at relative abundance of > 0.25 indiv/min. and BANO sampled at relative abundance of 0.01 indiv/min.	BPAU present less than 100% (absent during any survey) or present at relative abundance < 0.2 indiv/min. **AND/OR** BANO present less than 50% of time (absent during 2 consecutive surveys).	Significant change in instream vegetation habitats (to be quantified with RHAM).	BPAU	TSPA	Any decreased FROC in reach of BPAU and TSPA (refer to FROC, column F: Table 2).	

1 Refer to electronic data (DWA, 2010a).

5.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES/REC (C)		AEC up (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
ASCL	***Austroglanis sclateri* (Boulenger, 1901)**	**2**	**2**	**1**	**2**
BAEN	***Labeobarbus aeneus* (Burchell, 1822)**	**5**	**5**	**4**	**5**
BANO	***Barbus anoplus* (Weber, 1897)**	**2**	**1**	**0**	**1.5**
BKIM	***Labeobarbus kimberleyensis* (Gilchrist and Thompson, 1913)**	**3**	**2**	**1**	**2.5**
BPAU	***Barbus paludinosus* (Peters, 1852)**	**2**	**2**	**1**	**2**
CGAR	***Clarias gariepinus* (Burchell, 1822)**	**3**	**3**	**2**	**3**
LCAP	***Labeo capensis* (Smith, 1841)**	**5**	**4**	**3**	**5**
LUMB	***Labeo umbratus* (Smith, 1841)**	**3**	**2**	**1**	**2**
PPHI	***Pseudocrenilabrus philander* (Weber, 1897)**	**3**	**2**	**1**	**2**
TSPA	*Tilapia sparrmanii* (Smith, 1840)	2	1	0	1
(species in bold sampled at EWR site during baseline surveys)					

5.6 MACROINVERTEBRATES

5.6.1 Reference Conditions

Reference conditions are based on professional judgment and data collected by Dr Mark Chutter from his Sites 3 and 5 (Chutter, 1967: Table 11). The reference SASS5 Score is 183 and the ASPT is 6.5.

5.6.2 Baseline Description

Baseline biomonitoring data available for EWR 2 are summarised as follows:

Date	SASS5 Score	ASPT	No. of Taxa	Category (Dallas 2007)	MIRAI (%)	PES
08 - 04 - 08	110	5.5	20	C/D	71.1%	C
18 - 09 - 07	141	5.6	25	C		

5.6.3 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration, were recorded at the site during baseline sampling, and were selected as monitoring indicators for EWR 2.

Family	Flow				Substrate					Water Quality		
	Standing (<0.1 m/s)	Slow (0.1 - 0.3 m/s)	Mod (0.3 - 0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Vegetation	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7 - 10)	Low (SASS 4 - 6)
Hydropsychidae (>2 spp)			●	⬤	●	⬤	●			12		
Baetidae (>2 spp)	●	●	⬤	⬤	●	●	⬤	●	●		10	
Leptophlebiidae (Prongills)	●	⬤	●		●	●	⬤	●	⬤		9	
Tricorythidae (Stout crawlers)			●	⬤	●	⬤	⬤	●			9	
Atyidae (Freshwater shrimps)		●						⬤			8	
Simuliidae (Blackflies)		●	⬤	⬤	⬤	⬤	⬤	⬤				5
Heptageniidae (Flathead mayflies)		●	●	●		●	⬤	●		13		
Perlidae (Stoneflies)			●	⬤		●	⬤			12		
Psephenidae (Water pennies)			●	⬤		⬤	●				10	
Athericidae		●	⬤			●	⬤	●			10	
Elmiidae (Riffle beetles)			●	⬤		⬤	●	●			8	
Lestidae	●	●						⬤			8	
Ancylidae	●	●	●	●	●	●	●	●				6
Caenidae (Squaregills)	●	⬤				●	⬤	●	●			6
Hydropsychidae (2 spp)			●	⬤	●	⬤	●					5
Dytiscidae (Diving beetles)	⬤	●						⬤				5

● = Partial Preference ⬤ = Strong Preference

Caddisflies recorded at the site during baseline sampling included *Cheumatopsyche thomasseti, C. afra, Amphipysche scottae* and *Macrostenum capense.* Blackflies recorded at the site during baseline conditions were *Simulium adersi* and *S. damnosum*, both potential pest species of poultry and livestock respectively. Freshwater shrimps (Atyidae) were common in September 2007.

5.6.4 EcoSpecs and TPCs

EcoSpecs and TPCs for the PES and REC (C EC) at EWR 2 are provided below.

ECOSPECS: Biota	TPCs
SASS5 Score between 102 and 140.	SASS5 Score < 105.
ASPT between 5.4 and 5.9.	ASPT < 5.5.
MIRAI Score between 62% and 77%.	MIRAI Score < 65%.
To ensure that no group consistently dominates the fauna, defined as C abundance (> 100) over two consecutive surveys.	Any taxon abundance 'D' (> 1000) in two consecutive surveys.
Hydropsychidae > 2 spp.	Hydropsychidae < 2 spp.
Baetidae > 2 spp.	Baetidae < 2 spp.
Leptophlebiidae present.	Leptophlebiidae absent from two or more consecutive surveys.
Tricorythidae present (except winter).	Tricorythidae absent from two or more consecutive surveys (except winter).
Atyidae present.	Atyidae absent on two or more consecutive surveys.
Simuliidae present.	Simuliidae absent on two or more consecutive surveys.

6 EWR 3: GLADDEDRIFT (VAAL RIVER)

A summary of the EcoClassification results are provided below (DWA, 2009c).

6.1 ECOCLASSIFICATION SUMMARY OF EWR 3

EWR 3 Gladdedrift (Vaal River)

EIS: MODERATE

PES: C

Combination of flow and non - flow related impacts. Impacts mostly related to changes in flow regime due to Grootdraai Dam, illegal irrigation, livestock farming and vegetation removal.

REC: C

Maintain the PES due to the **MODERATE** EIS rating. However note that there is rare and endangered *Labeobarbus kimberleyensis* present which warrants improvement of the fish EC.

AEC Up: B

Improved base flows (no zero flows), and increased frequency of moderate floods.
Improved water quality due to improved flow regime.
Removal of cattle grazing in the marginal zone.

AEC Down: C/D

Increased duration of zero flow periods.
Decreased frequency of floods.
Very low base flows in the dry season when flowing.

Driver Components	PES and REC Category	Trend	AEC↑	AEC↓
HYDROLOGY	C			
WATER QUALITY	C	Stable	B/C	D
GEOMORPHOLOGY	C	Stable	C	D
Response Components	**PES Category**	**Trend**	**AEC↑**	**AEC↓**
FISH	C	Stable	B	D
MACRO INVERTEBRATES	C	Stable	B/C	D
INSTREAM	C		B	D
RIPARIAN VEGETATION	C	Stable	B	C
ECOSTATUS	C		B	C/D

EcoSpecs and TPCs for EWR 3 are provided for the different components in Section 6.2 to 6.7.

6.2 GEOMORPHOLOGY

EcoSpecs and TPCs based on the GAI are provided in Section 6.2.1.

6.2.1 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Descriptor	EcoSpec	TPC
Bed material composition	Sampling of the dry season bed material at the EWR site (using a sample size of not less than 500 points) should be undertaken at the prescribed intervals (every 5 years) to assess impacts of flow on the bed sediment and therefore as an indication of the change of available habitat for instream biota. Fining of the bed (i.e. decreases in the size of the 16th, 50th and 84th percentiles of the sediment size distribution as indicated to the left) would indicate insufficient flows being delivered to the site to maintain the geomorphological condition.	
	D_{16} = 5 mm	D_{16} sediment size must be greater than 2 mm
	D_{50} = 30 mm	D_{50} sediment size must be greater than 20 mm
	D_{84} = 100 mm	D_{84} sediment size must be greater than 50 mm
Channel morphology	As with EWR 2, the reference condition at this site would have had fewer cut banks (the site is located immediately below a bridge which is causing localised erosion, and also the large Grootdraai Dam is upstream). To maintain the PES, no further channel incision can occur. Incised channels overtop less frequently and cause desiccation of the upper riparian and floodplain areas. Incision can be monitored through resurveyed cross - sections.	
		Any deepening of the channel (pool) or widening and/or steepening of the banks at cross section scale.

6.3 PHYSICO - CHEMICAL VARIABLES

EcoSpecs and TPCs are provided in Section 6.3.1 – 6.3.2.

6.3.1 EcoSpecs relating to physico - chemical data: PES and REC

River: Vaal		EWR 3
Water quality metrics		**EcoSpec: PES and REC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be ≤ 37 mg/L.
	Na_2SO_4	The 95th percentile of the data must be ≤ 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be ≤ 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be ≤ 21 mg/L.
	NaCl	The 95th percentile of the data must be ≤ 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be ≤ 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be ≤ 50 mS/m.
	pH	The 5th and 95th percentiles of the data must range from 6.5 to 8.8.
	Temperature	Small deviation from the natural temperature range.
	Dissolved oxygen	The 5th percentile of the data must be ≥ 7.5 mg/L.
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
Nutrients	TIN	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
	PO_4 - P	The 50th percentile of the data must be ≤ 0.16 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be ≤ 0.015 mg/L.
	Chl - a periphyton	The 50th percentile of the data must be <10 µg/L.
	Toxics	The 50th percentile of the data must be ≤ 21 mg/m^2.

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

6.3.2 TPCs relating to physico - chemical data

River: Vaal		EWR 3
Water quality metrics		**TPC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be 28 – 37 mg/L.
	Na_2SO_4	The 95th percentile of the data must be 16 – 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be 12 – 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be 17 – 21 mg/L.
	NaCl	The 95th percentile of the data must be 36 – 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be 280 – 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be < 50 mS/m.
	pH	The 5th and 95th percentiles of the data must be < 6.5 and > 8.5.
	Temperature	Initiate baseline monitoring for this variable.
	Dissolved oxygen	The 5th percentile of the data must be 7.8 – 7.5 mg/L.
Nutrients	TIN	The 50th percentile of the data must be 0.10 – 0.25 mg/L.
	PO_4 - P	The 50th percentile of the data must be 0.025 – 0.125 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be 8 – 10 µg/L.
	Chl - a periphyton	The 50th percentile of the data must be 17 – 21 mg/m^2.
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

The EWR site is upstream of the impacts of the Waterval River. The Waterval catchment is impacted by effluents from Sasol 2 and 3, Evander Goldmine, Evander and Secunda. The water quality data that has been used for this site is at Villiers (above the impacts of back flooding from the Vaal Dam) and downstream of the impacts from the Waterval catchment. Additional water quality monitoring required at EWR site to determine potential issues from upstream water use.

6.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the VEGRAI data are provided Section 6.4.1 to 6.4.2.

6.4.1 EcoSpec and TPC description relating to VEGRAI monitoring data: PES and REC

PES and REC	Assessed Component	Zone Assessed	EcoSpec (PES and REC)	TPC (PES and REC)	Baseline Note
C	Exotic Invasion (perennial exotics).	Marginal zone.	Maintain perennial exotic species cover below 20%.	An increase in perennial exotic species above 10%.	> 10% recorded during VEGRAI assessment; mostly non - perennial weeds but *Salix babylonica* occurred.
		Lower zone.	Maintain perennial exotic species cover below 20%.	An increase in perennial exotic species above 10%.	> 10% recorded during VEGRAI assessment with about 5% being perennial exotics (*S. babylonica, Senna didymobotrya*).
		Upper zone.	Maintain perennial exotic species cover below 20%.	A presence of perennial exotic species.	> 10% recorded during VEGRAI assessment but all exotics were non - woody annual weeds: no perennial exotic species were recorded.
	Terrestrial woody species cover.	Marginal zone.	Maintain the absence of terrestrial woody species.	The presence of terrestrial woody species.	No woody terrestrial species were recorded in the riparian zone.
		Lower zone.	Maintain cover of terrestrial woody species below 10%.	The presence of terrestrial woody species.	
		Upper zone.	Maintain cover of terrestrial woody species below 30%.	Increases in woody terrestrial species cover above 10%.	
	Indigenous Riparian Woody Cover.	Marginal zone.	Maintain indigenous riparian woody cover below 50%, but retain presence i.e. not 0%.	An absence of riparian woody cover OR an increase above 20%.	> 10% recorded *Gomphostigma virgatum* the only species.
		Lower zone.	Maintain indigenous riparian woody cover below 30%.	An increase in riparian woody cover above 10%.	0% recorded.
		Upper zone.	Maintain indigenous riparian woody cover below 25%.	An increase in riparian woody cover above 10%.	0% recorded.
	Non - woody Indigenous Cover (grasses, sedges and dicotyledonous forbs).	Marginal zone.	Maintain non - woody cover above 30%, with sedges predominating.	A decrease in non - woody cover below 60% OR and increase above 90%.	60 - 80% recorded during VEGRAI assessment.
		Lower zone.	Maintain non - woody cover above 40%.	A decrease in non - woody cover below 40%.	40 - 60% recorded during VEGRAI assessment.
		Upper zone.	Maintain non - woody cover above 20%, with grasses predominating.	A decrease in non - woody cover below 50%.	60 - 80% recorded during VEGRAI assessment.
	Phragmites (reed) cover.	Riparian zone.	Maintain the absence of reeds.	A presence of reeds.	Reeds were not observed at the site, and are not expected.

6.4.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data: PES and REC

Colour coding in the table below refers to:

EcoSpecs	TPC	Baseline	PES and REC

Class	Perennial Exotics (%)	Terrestrialization (%)	Riparian Woody (%)	Non-woody (%)	Reeds (%)
Marginal Zone					
A	0	0	5 - 10	70 - 80	0
A/B	1 - 5	0	10 - 20	60 - 70; 80 - 90	0
B	5 - 10	0	1 - 5; 20 - 30	50 - 60; >90	0
B/C	10 - 15	0	30 - 40	40 - 50	0
C	15 - 20	0	40 - 50	30 - 40	0
C/D	20 - 30	0	0; 50 - 60	20 - 30	1 - 5

Class	Perennial Exotics (%)	Terrestrialization (%)	Riparian Woody (%)	Non-woody (%)	Reeds (%)
D	30 - 50	1 - 5	60 - 70	10 - 20	5 - 10
D/E	50 - 60	5 - 10	70 - 80	1 - 10	10 - 15
E	60 - 70	10 - 15	80 - 90	0	15 - 20
E/F	70 - 80	15 - 20	>90		20 - 25
F	>80	>20			>25
Lower Zone					
A	0	0	0 - 5	80 - 90	0
A/B	1 - 5	0	5 - 10	70 - 80; >90	0
B	5 - 10	0	10 - 15	60 - 70	0
B/C	10 - 15	1 - 5	15 - 20	50 - 60	0
C	15 - 20	5 - 10	20 - 30	40 - 50	0
C/D	20 - 30	10 - 15	30 - 40	30 - 40	1 - 10
D	30 - 50	15 - 20	40 - 50	20 - 30	10 - 20
D/E	50 - 60	20 - 30	50 - 60	10 - 20	20 - 30
E	60 - 70	30 - 40	60 - 70	5 - 10	30 - 40
E/F	70 - 80	40 - 50	70 - 80	1 - 5	40 - 50
F	>80	>50	>80		>50
Upper Zone					
A	0	0 - 5	0 - 5	80 - 90	0
A/B	1 - 5	5 - 10	5 - 10	70 - 80; >90	0
B	5 - 10	10 - 15	10 - 15	50 - 70	0
B/C	10 - 15	15 - 20	15 - 20	30 - 50	0
C	15 - 20	20 - 30	20 - 25	20 - 30	0
C/D	20 - 30	30 - 40	25 - 30	1 - 20	0
D	30 - 50	40 - 50	30 - 40	0	1 - 5
D/E	50 - 60	50 - 60	40 - 50		5 - 10
E	60 - 70	60 - 70	50 - 60		10 - 15
E/F	70 - 80	70 - 80	60 - 70		15 - 20
F	>80	>80	>70		>20

6.5 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 6.5.1. The spatial FROC of EWR 3 is provided in Section 6.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

6.5.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES					REC
			EWR SITE			REACH		REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
5	Species richness.	All indigenous species.	Eight expected indigenous fish sp to be sampled (as per EWR baseline survey).	Less than five species sampled during any survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity - depth categories and cover features (to be quantified by RHAM if applicable).	All indigenous species.	Baseline (PES) FRAI score of 76.7% (high C) calculated for the reach. Any decreased FROC in reach of especially ASCL, BAEN BKIM and LCAP (refer to sheet 5 - FROC: Table 2) OR FRAI scores decreasing below 68% (low category C).	An improvement from PES FROC in the reach for especially ASCL, BKIM, LUMB and TSPA should be indicative of reaching/maintaining the improved AEC (refer to 5 - FROC sheet for more detail).
4	Relative abundance.	All indigenous species.	Fish sampled at > 0.8 individuals per minute (electrofishing).	Relative abundance of less than 0.6 individual per minute sampled at the site (during same seasons as baseline data) when habitat can be sampled efficiently using electrofishing.	N/A	N/A	N/A	
10	Alien fish species.	Any alien/introduced spp.	Two alien fish species (GAFF and CCAR) sampled at site during survey. CCAR present 100% at a relative abundance of < 0.012 indiv/min for CCAR and GAFF 50% of time at 0.07 indiv/min. (Two additional species namely MSAL and CIDE known to be present in the reach).	Increase in the number of alien species (> 2 species during any survey) **OR** increased relative abundance of CCAR > 0.03 indiv/min.	N/A	Any alien/introduced spp.	Increase in the number of alien species (> 4 species in reach) OR presence of any alien species other than CCAR, GAFF, MSAL and CIDE.	
1	FD and SD habitats, substrate, flow dependant spp (flow alteration), water column.	BAEN, LCAP	BAEN and LCAP sampled 100% of time. BAEN present at relative abundance of > 0.5 indiv/min. and LCAP sampled at relative abundance of > 0.2 indiv/min.	BAEN and LCAP present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.4 indiv/min for BAEN and < 0.1 indiv/min for LCAP.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows), Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools), Reduction in suitability of water column (i.e. increased sedimentation of pools). To be quantified with RHAM.	BAEN LCAP	Any decreased FROC in reach of BAEN and LCAP (refer to sheet 5 - FROC, column F: Table 2).	
2	FS habitats.	BAEN, ASCL	BAEN sampled 100% of time while ASCL sampled 50% of time. BAEN present at relative abundance of > 0.5 indiv/min. and ASCL sampled at relative	BAEN present less than 100% of time (not sampled during any survey) **OR** decrease in relative abundance of < 0.4 indiv/min OR ASCL present less than 50% of time	I.e. decreased flows, increased zero flows. To be quantified with RHAM.	BAEN ASCL	Any decreased FROC in reach of BAEN and ASCL (refer to sheet 5 - FROC, column F: Table 2).	

Rank	Metric	Indicator spp.	PES						REC
			EWR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
			abundance of 0.01 indiv/min.	(not sampled during 2 consecutive surveys).					
1	Water quality intolerance.	LCAP, BAEN	BAEN and LCAP sampled 100% of time. BAEN present at relative abundance of > 0.5 indiv/min. and LCAP sampled at relative abundance of > 0.2 indiv/min.	BAEN **OR** LCAP present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.4 indiv/min for BAEN and < 0.1 indiv/min for LCAP.	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	BKIM	LCAP	Any decreased FROC in reach of BKIM and LCAP (refer to sheet 5 - FROC, column F: Table 2).	
9	SS habitats.	PPHI, CGAR	PPHI and CGAR sampled 100% of time. PPHI present at relative abundance of > 0.02 indiv/min. and CGAR sampled at relative abundance of > 0.006 indiv/min.	PPHI **AND** CGAR present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.01 indiv/min for PPHI.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats). To be quantified with RHAM.	PPHI	CGAR	Any decreased FROC in reach of PPHI and CGAR (refer to sheet 5 - FROC, column F: Table 2).	
7	Overhanging vegetation.	PPHI, BPAU and BANO	PPHI sampled 100% while BANO and BPAU sampled 50% of time a. PPHI present at relative abundance of > 0.02 indiv/min, BPAU sampled at relative abundance of 0.006 indiv/min and BANO at 0.03 indiv/min.	PPHI present less than 100% of time (not sampled during any survey) **OR** decrease in relative abundance of < 0.01 indiv/min for PPHI **AND/OR** absence of BANO **OR** BPAU during consecutive surveys.	Significant change in overhanging vegetation habitats (to be quantified with RHAM).	PPHI	TSPA	Any decreased FROC in reach of PPHI and TSPA (refer to sheet 5 - FROC, column F: Table 2).	
6	Undercut banks.	ASCL, PPHI	PPHI sampled 100% while ASCL sampled 50% of time a. PPHI present at relative abundance of > 0.02 indiv/min, ASCL sampled at relative abundance of 0.01 indiv/min.	PPHI present less than 100% of time (not sampled during any survey) **OR** decrease in relative abundance of < 0.01 indiv/min for PPHI **AND/OR** ASCL present less than 50% of time (not sampled during 2 consecutive surveys).	Significant change in undercut bank habitats (to be quantified with RHAM).	ASCL	PPHI	Any decreased FROC in reach of ASCL and PPHI (refer to sheet 5 - FROC, column F: Table 2).	
8	Instream vegetation.	BPAU, BANO	BANO and BPAU sampled 50% of time. BPAU sampled at relative abundance of 0.006 indiv/min and BANO at 0.03 indiv/min.	Absence of BANO **OR** BPAU during consecutive surveys.	Significant change in instream vegetation habitats (to be quantified with RHAM).	BPAU	TSPA	Any decreased FROC in reach of BPAU and TSPA (refer to sheet 5 - FROC, column F: Table 2).	

1 Refer to electronic data (DWA, 2010a).

6.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES/REC (C)		AEC up (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
ASCL	***Austroglanis sclateri* (Boulenger, 1901)**	**3**	**2**	**1**	**2.5**
BAEN	***Labeobarbus aeneus* (Burchell, 1822)**	**5**	**5**	**4**	**5**
BANO	***Barbus anoplus* (Weber, 1897)**	**2**	**2**	**1**	**2**
BKIM	***Labeobarbus kimberleyensis* (Gilchrist and Thompson, 1913)**	**3**	**2**	**1**	**2.5**
BPAU	***Barbus paludinosus* (Peters, 1852)**	**2**	**2**	**1**	**2**
CGAR	***Clarias gariepinus* (Burchell, 1822)**	**3**	**3**	**2**	**3**
LCAP	***Labeo capensis* (Smith, 1841)**	**5**	**5**	**4**	**5**
LUMB	*Labeo umbratus* (Smith, 1841)	2	1	0	2
PPHI	***Pseudocrenilabrus philander* (Weber, 1897)**	**3**	**3**	**2**	**3**
TSPA	*Tilapia sparrmanii* (Smith, 1840)	2	1	0	1.5
(species in bold sampled at EWR site during baseline surveys)					

6.6 MACROINVERTEBRATES

6.6.1 Reference Conditions

Reference conditions are based on professional judgment and data collected by Dr Mark Chutter from his Sites 5A (this site) and 6 (Chutter, 1967: Table 11). The reference SASS5 Score is 172 and the ASPT is 5.9.

6.6.2 Baseline Description

Baseline biomonitoring data available for EWR 3 are summarised as follows:

Date	SASS5 Score	ASPT	No. of Taxa	Category (Dallas 2007)	MIRAI (%)	PES
08-04-08	120	6.0	20	C/D	67.0%	C
17-09-07	103	5.2	20	D		

6.6.3 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration, were recorded at the site during baseline sampling, and were selected as monitoring indicators for EWR 3.

Family	Flow				Substrate					Water Quality		
	Standing (<0.1 m/s)	Slow (0.1 - 0.3 m/s)	Mod (0.3 - 0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Vegetation	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7 - 10)	Low (SASS 4 - 6)
Baetidae (>2 spp)	●	●	⬤	⬤	●	●	⬤	●	●		10	
Leptophlebiidae (Prongills)	●	⬤	●		●	●	⬤	●	⬤		9	
Tricorythidae (Stout crawlers)			●	⬤	●	⬤	⬤	●			9	
Hydropsychidae (2 spp)			●	⬤	●	⬤	●					5
Simuliidae (Blackflies)		●	⬤	⬤	⬤	⬤	⬤	⬤				5
Heptageniidae (Flathead mayflies)		●	●	●		●	⬤	●		13		
Hydropsychidae (>2 spp)			●	⬤	●	⬤	●			12		
Perlidae (Stoneflies)			●	⬤		●	⬤			12		
Psephenidae (Water pennies)			●	⬤		⬤	●				10	
Athericidae		●	⬤			●	⬤	●			10	
Atyidae (Freshwater shrimps)		●						⬤			8	
Elmiidae (Riffle beetles)			●	⬤		⬤	●	●			8	
Lestidae	●	●						⬤			8	
Ancylidae	●	●	●	●	●	●	●	●				6
Caenidae (Squaregills)	●	⬤				●	⬤	●	●			6
Dytiscidae (Diving beetles)	⬤	●						⬤				5

● = Partial Preference ⬤ = Strong Preference

Caddisflies recorded at the site during baseline sampling included *Cheumatopsyche thomasseti, Amphipysche scottae* and *Macrostenum capense.* Blackflies recorded at the site during baseline conditions were *Simulium adersi* and *S. damnosum* (mostly), both potential pest species of poultry and livestock respectively. Freshwater shrimps (Atyidae) were noticeably absent. In September 2007 their absence was attributed to limited availability of marginal vegetation because of very low flows. In April 2008 the marginal vegetation was suitable for shrimps, but they were not recorded, presumably because the populations had not recovered from the previous low flows.

6.6.4 EcoSpecs and TPCs relating to the MIRAI data: PES and REC

EcoSpecs and TPCs for the PES and REC (C) at EWR 3 are provided below:

ECOSPECS: Biota	TPCS
SASS5 Score between 97 and 127.	SASS5 Score < 104.
ASPT between 5.1 and 5.9.	ASPT < 5.4.
MIRAI Score between 62% and 77%.	MIRAI Score < 64%.
To ensure that no group consistently dominates the fauna, defined as C abundance (> 100) over two consecutive surveys.	Any taxon abundance 'D' (> 1000) in two consecutive surveys.
Baetidae > 2 spp.	Baetidae < 2 spp.
Leptophlebiidae present.	Leptophlebiidae absent from two or more consecutive surveys.

ECOSPECS: Biota	TPCS
Tricorythidae present (except winter).	Tricorythidae absent from two or more consecutive surveys (except winter).
Hydropsychidae > 2 spp.	Hydropsychidae < 2 spp.
Simuliidae present.	Simuliidae absent on two or more consecutive surveys.

7 EWR 4: DE NEYS (VAAL RIVER)

A summary of the EcoClassification results are provided below (DWA, 2009c).

7.1 ECOCLASSIFICATION SUMMARY OF EWR 4

EWR 4: De Neys (Vaal River)

EIS: HIGH
The presence of the rare and endangered *Labeobarbus kimberleyensis*.
The Vaal River being a large river, which is rare in South Africa.
The diversity of riparian and instream habitats which include runs, rocky outcrops and rapids as well as pools.
Important refugia such as pools.
Being the only area between the Vaal Dam and barrage where yellowfish can breed.

PES: C
Impacts are mostly due to flow related problems, especially the presence of Vaal Dam and lack of flow variability. Increased base flows (dry season) occur as well as reduced frequencies of moderate floods due to releases from the Vaal Dam to maintain a target TDS concentration of 600 mg/l downstream of Vaal Barrage. .

REC: B/C

Improvement of PES due to **HIGH** EIS rating. A B EcoStatus could not be attained due to the limited operational possibilities from the Vaal Dam. Scenario includes improvement of seasonal variability (decreased base flows during the dry season and increased wet season flows above the current base flows).

AEC Down: D

Increased constant base flows if salinity problems are exacerbated leading to a loss of variability.
Decreased frequency of floods.

IHI			Driver Components	PES and REC Category	Trend	AEC↑	AEC↓
INSTREAM	D	RIPARIAN D	HYDROLOGY	D/E			
			WATER QUALITY	C	Stable	C	C/D
			GEOMORPHOLOGY	D	Stable	D	D
			Response Components	PES Category	Trend	AEC↑	AEC↓
			FISH	C	Stable	B	D
			MACRO INVERTEBRATES	C/D	Stable	C	C/D
			INSTREAM	C		B/C	D
			RIPARIAN VEGETATION	C	Stable	B/C	D
			ECOSTATUS	C		B/C	D

EcoSpecs and TPCs of EWR 4 are provided for the different components in Section 7.2 to 7.7.

7.2 GEOMORPHOLOGY

EcoSpecs and TPCs based on the GAI are provided in Section 7.2.1.

7.2.1 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Descriptor	EcoSpec	TPC
Bed material composition	Sampling of the dry season bed material at the EWR site (using a sample size of not less than 500 points) should be undertaken at the prescribed intervals (every 5 years) to assess impacts of flow on the bed sediment and therefore as an indication of the change of available habitat for instream biota. Fining of the bed (i.e. decreases in the size of the 16th, 50th and 84th percentiles of the sediment size distribution as indicated to the left) would indicate insufficient flows being delivered to the site to maintain the geomorphological condition. Coarsening of the bed (increasing the sediment sizes) would indicate further elevated flows, bed - armouring and loss of fine - sediment habitat types.	
	D_{16} = 20 mm	D_{16} sediment size must be between 10 - 25 mm
	D_{50} = 140 mm	D_{50} sediment size must be between 100 - 180 mm
	D_{84} = 320 mm	D_{84} sediment size must be between 300 - 400 mm
Channel morphology	Grootdraai Dam is upstream of the site and this has cut off sediment supply and critical reduced moderate and large floods. This has resulted in coarsened bed material. To maintain the PES, no further channel incision can occur. Incision can be monitored through resurveyed cross - sections.	
		Any deepening of the channel at cross section scale.

7.3 PHYSICO - CHEMICAL VARIABLES

TPCs and EcoSpecs are provided in Section 7.3.1 – 7.3.2.

7.3.1 EcoSpecs relating to physico - chemical data: PES and REC

River: Vaal		EWR 4
Water quality metrics		**EcoSpecs: PES and REC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be ≤ 37 mg/L.
	Na_2SO_4	The 95th percentile of the data must be ≤ 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be ≤ 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be ≤ 21 mg/L.
	NaCl	The 95th percentile of the data must be ≤ 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be ≤ 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be ≤ 30 mS/m.
	pH	The 5th and 95th percentiles of the data must range from 6.5 to 8.5.
	Temperature	Small deviation from the natural temperature range.
	Dissolved oxygen	The 5th percentile of the data must be ≥ 6 mg/L.
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
Nutrients	TIN	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
	PO_4 - P	The 50th percentile of the data must be ≤ 0.7 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be ≤ 0.015 mg/L.
	Chl - a periphyton	The 50th percentile of the data must be <10 µg/L.
	Toxics	The 50th percentile of the data must be ≤ 21 mg/m^2.

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

7.3.2 TPCs relating to physico - chemical data

River: Vaal		EWR 4
Water quality metrics		**TPC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be 28 – 37 mg/L.
	Na_2SO_4	The 95th percentile of the data must be 16 – 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be 12 – 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be 17 – 21 mg/L.
	NaCl	The 95th percentile of the data must be 36 – 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be 280 – 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be < 30 mS/m.
	pH	The 5th and 95th percentiles of the data must be < 6.5 and > 8.5.
	Temperature	Initiate baseline monitoring for this variable.
	Dissolved oxygen	The 5th percentile of the data must be 7.8 – 7.5 mg/L.
Nutrients	TIN	The 50th percentile of the data must be 0.25 – 0.7 mg/L.
	PO_4 - P	The 50th percentile of the data must be 0.025 – 0.125 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be 15 – 21 µg/L.
	Chl - a periphyton	The 50th percentile of the data must be 17 – 21 mg/m^2.
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

The upstream catchment patterns and natural sediments in the Vaal catchment are known to cause naturally large increases in sediment loads and turbidity (hence the system is known as the

Vaal River system). Seasonally the habitat often silted but it is cleared from time to time when large floods come through this system. The dissolved oxygen and temperatures will be impacted by the Vaal Dam and these are further complicated by the Vaal Barrage.

7.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the VEGRAI data are provided Section 7.4.1 to 7.4.2.

7.4.1 EcoSpec and TPC description relating to VEGRAI monitoring data: PES and REC

PES	REC	Assessed Component	Zone Assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Baseline Note
C	B/C	Exotic Invasion (perennial exotics).	Marginal zone.	Maintain perennial exotic species cover below 20%.	An increase in perennial exotic species above 15%.	Maintain perennial exotic species cover below 15%.	10 - 20% recorded during VEGRAI assessment; mostly non - perennial weeds but *S. babylonica* occurred.
			Lower zone.	Maintain perennial exotic species cover below 20%.	An increase in perennial exotic species above 15%.	Maintain perennial exotic species cover below 15%.	10 - 20% recorded during VEGRAI assessment with about 15% being perennial exotics (*S. babylonica, Acacia mearnsii).*
			Upper zone.	Maintain perennial exotic species cover below 20%.	An increase in perennial exotic species above 30%.	Maintain perennial exotic species cover below 15%.	20 - 40% recorded during VEGRAI assessment with about 30% being perennial exotics (*A. mearnsii, Eucalyptus camaldulensis, and Melia azedarach*).
		Terrestrial woody species cover.	Marginal zone.	Maintain the absence of terrestrial woody species.	The presence of terrestrial woody species.	Maintain the absence of terrestrial woody species.	No woody terrestrial species were recorded.
			Lower zone.	Maintain cover of terrestrial woody species below 10%.	The presence of terrestrial woody species.	Maintain cover of terrestrial woody species below 5%.	No woody terrestrial species were recorded.
			Upper zone.	Maintain cover of terrestrial woody species below 50%.	An increase in woody terrestrial species covers above 20%.	Maintain cover of terrestrial woody species below 40%.	Approximately 15% cover by woody terrestrial species recorded during the VEGRAI assessment.
		Indigenous Riparian Woody Cover.	Marginal zone.	Maintain indigenous riparian woody cover below 50%, but retain presence i.e. not 0%.	An absence of riparian woody cover OR an increase above 20%.	Maintain indigenous riparian woody cover below 40%, but retain presence i.e. not 0%.	< 10% recorded only *G. virgatum* and *S. mucronata.*
			Lower zone.	Maintain indigenous riparian woody cover below 30%.	An increase in riparian woody cover above 20%.	Maintain indigenous riparian woody cover below 20%.	10 - 20% recorded, only *S. mucronata.*
			Upper zone.	Maintain indigenous riparian woody cover between 20 and 70%.	An increase in riparian woody cover above 70% OR below 20%.	Maintain indigenous riparian woody cover between 30 and 60%.	10 - 20% recorded, only *Celtis africana* and *Diospyros lyciodes.*
		Non - woody Indigenous Cover (grasses, sedges and dicotyledonous forbs).	Marginal zone.	Maintain non - woody cover above 30%, with sedges predominating.	A decrease in non - woody cover below 50%.	Maintain non - woody cover above 40%, with sedges predominating.	60 - 80% recorded during VEGRAI assessment.
			Lower zone.	Maintain non - woody cover above 40%.	A decrease in non - woody cover below 60%.	Maintain non - woody cover above 50%.	80 - 100% recorded during VEGRAI assessment.
			Upper zone.	Maintain non - woody cover below 90%.	An absence of non - woody cover OR an increase above 80%.	Maintain non - woody cover below 80%.	60 - 80% recorded during VEGRAI assessment.
		Phragmites (reed) cover.	Riparian zone.	Maintain the absence of reeds.	A presence of reeds.	Maintain the absence of reeds.	Reeds were observed on the marginal and lower zones, but cover was small.

7.4.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data: PES and REC

Colour coding in the table below refers to:

EcoSpecs	TPC	Baseline	PES	REC

Class	Perennial Exotics (%)	Terrestrialization (%)	Riparian Woody (%)	Non-woody (%)	Reeds (%)
Marginal Zone					
A	0	0	5 - 10	70 - 80	0
A/B	1 - 5	0	10 - 20	60 - 70; 80 - 90	0
B	5 - 10	0	1 - 5; 20 - 30	50 - 60; >90	0
B/C	10 - 15	0	30 - 40	40 - 50	0
C	15 - 20	0	40 - 50	30 - 40	0
C/D	20 - 30	0	0 ; 50 - 60	20 - 30	1 - 5
D	30 - 50	1 - 5	60 - 70	10 - 20	5 - 10
D/E	50 - 60	5 - 10	70 - 80	1 - 10	10 - 15
E	60 - 70	10 - 15	80 - 90	0	15 - 20
E/F	70 - 80	15 - 20	>90		20 - 25
F	>80	>20			>25
Lower Zone					
A	0	0	0 - 5	80 - 90	0
A/B	1 - 5	0	5 - 10	70 - 80; >90	0
B	5 - 10	0	10 - 15	60 - 70	0
B/C	10 - 15	1 - 5	15 - 20	50 - 60	0
C	15 - 20	5 - 10	20 - 30	40 - 50	0
C/D	20 - 30	10 - 15	30 - 40	30 - 40	1 - 10
D	30 - 50	15 - 20	40 - 50	20 - 30	10 - 20
D/E	50 - 60	20 - 30	50 - 60	10 - 20	20 - 30
E	60 - 70	30 - 40	60 - 70	5 - 10	30 - 40
E/F	70 - 80	40 - 50	70 - 80	1 - 5	40 - 50
F	>80	>50	>80		>50
Upper Zone					
A	0	0 - 10	40 - 50	40 - 50	0
A/B	1 - 5	10 - 20		20 - 30; 50 - 60	0
B	5 - 10	20 - 30	30 - 40; 50 - 60	10 - 20; 60 - 70	0
B/C	10 - 15	30 - 40		1 - 10; 70 - 80	0
C	15 - 20	40 - 50	20 - 30; 60 - 70	0; 80 - 90	0
C/D	20 - 30	50 - 60		>90	0
D	30 - 50	60 - 70	10 - 20; 70 - 80		1 - 5
D/E	50 - 60	70 - 80			5 - 10
E	60 - 70	80 - 90	5 - 10; 80 - 90		10 - 15
E/F	70 - 80	>90			15 - 20
F	>80		<5; >90		>20

7.5 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 7.5.1. The spatial FROC of EWR 4 is provided in Section 7.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

7.5.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES						REC
			EWR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
2	Species richness.	All indigenous species.	Seven expected indigenous fish sp to be sampled (as per EWR baseline survey).	Less than six fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity - depth categories and cover features (to be quantified by RHAM).	All indigenous species.		Baseline (PES) FRAI score of 66.7 (C) calculated for the reach. Any decreased FROC in reach of especially BAEN, LCAP, ASCL and BKIM (refer to FROC: Table 2[1]) OR FRAI scores decreasing below 62,02% (category C/D).	An improvement from PES FROC in the reach for especially ASCL, BAEN, BANO, BKIM and TSPA should be indicative of reaching/maintaining the REC (refer to FROC sheet for more detail).
3	Relative abundance.	All indigenous species.	Fish were sampled at > 0.8 individuals per minute (electrofishing).	Relative abundance of less than 0.6 individual per minute sampled at the site (during same season as baseline data) when habitat can be sampled efficiently using electrofishing.	N/A	N/A		N/A	
5	Alien fish species.	Any alien/introduced spp.	No alien fish.	Presence of any alien/introduced fish species at site during any survey.	N/A	Any alien/introduced spp.		Increase in the number of alien species (>4 species in reach) OR presence of any alien species other than CCAR, GAFF, MSAL and CIDE.	
1	FD, SD habitats, substrate, flow dependant spp (flow alteration), water column.	BAEN, LCAP	BAEN and LCAP sampled 100% of the time. BAEN present at relative abundance of > 0.1 indiv/min. and LCAP sampled at relative abundance of > 0.28 indiv/min.	BAEN and LCAP present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.05 indiv/min for BAEN and < 0.2 indiv/min for LCAP.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows), Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates. [To be quantified with RHAM]. Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools), Reduction in suitability of water column (i.e. increased sedimentation of pools).	BAEN	LCAP	Any decreased FROC in reach of BAEN and LCAP (refer to FROC, column F: Table 2).	
1	FS habitats.	BAEN	BAEN sampled 100% of the time. BAEN present at relative abundance of > 0.1 indiv/min.	BAEN present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.05 indiv/min.	Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows). [To be quantified with RHAM].	BAEN	ASCL	Any decreased FROC in reach for BAEN and ASCL (refer to FROC, column F: Table 2).	
2	Water quality intolerance.	BAEN, LCAP	BAEN and LCAP sampled 100% of the time. BAEN present at relative abundance of > 0.1 indiv/min. and LCAP sampled at relative abundance of > 0.28 indiv/min.	BAEN and LCAP present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.05 indiv/min for BAEN and < 0.2 indiv/min for LCAP.	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	BKIM	LCAP	Any decreased FROC in reach of BKIM and LCAP (refer to FROC, column F: Table 2).	

Rank	Metric	Indicator spp.	PES						REC
			EWR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
4	SS habitats, overhanging vegetation.	PPHI, TSPA	PPHI sampled 100% of time, present at relative abundance of > 0.04 indiv/min. TSPA sampled 50% of time, and sampled at relative abundance of > 0.02 indiv/min.	PPHI present less than 100% of time (not sampled during any survey), **OR** present at relative abundance of < 0.02 indiv/min **AND/OR** TSPA absent during two consecutive surveys.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats). Significant change in overhanging vegetation habitats (to be quantified with RHAM).	PPHI	TSPA	Any decreased FROC in reach of PPHI and TSPA (refer to FROC, column F: Table 2).	
2	Undercut banks.	PPHI	PPHI sampled 100% of time, present at relative abundance of > 0.04 indiv/min.	PPHI present less than 100% of time (not sampled during any survey) **OR** present at relative abundance of < 0.02 indiv/min.	Significant change in undercut bank habitats (to be quantified with RHAM).	ASCL	PPHI	Any decreased FROC in reach of ASCL and PPHI (refer to FROC, column F: Table 2).	
3	Instream vegetation.	BPAU, TSPA	BPAU sampled 100% of time, present at relative abundance of > 0.1 indiv/min. TSPA sampled 50% of time, and sampled at relative abundance of > 0.02 indiv/min.	BPAU present less than 100% of time (not sampled during any survey) OR present at relative abundance of < 0.07 indiv/min. TSPA absent during two consecutive surveys.	Significant change in instream vegetation habitats (to be quantified with RHAM).	BPAU	TSPA	Any decreased FROC in reach of BPAU and TSPA (refer to FROC, column F: Table 2).	

1 Refer to electronic data (DWA, 2010a).

7.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (C)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
ASCL	*Austroglanis sclateri* (Boulenger, 1901)	3	2	1	3
BAEN	***Labeobarbus aeneus* (Burchell, 1822)**	**4**	**3**	**2**	**4**
BANO	*Barbus anoplus* (Weber, 1897)	2	1	0	2
BKIM	*Labeobarbus kimberleyensis* (Gilchrist and Thompson, 1913)	3	1	0	2
BPAU	***Barbus paludinosus* (Peters, 1852)**	**3**	**3**	**2**	**3**
CGAR	***Clarias gariepinus* (Burchell, 1822)**	**3**	**3**	**2**	**3**
LCAP	***Labeo capensis* (Smith, 1841)**	**4**	**3**	**2**	**3**
LUMB	***Labeo umbratus* (Smith, 1841)**	**3**	**2**	**1**	**2**
PPHI	***Pseudocrenilabrus philander* (Weber, 1897)**	**3**	**3**	**2**	**3**
TSPA	***Tilapia sparrmanii* (Smith, 1840)**	**3**	**2**	**1**	**3**
(species in bold sampled at EWR site during baseline surveys)					

7.6 MACROINVERTEBRATES

7.6.1 Reference Conditions

Reference conditions are based on professional judgment and data collected by Dr Mark Chutter from his Sites 5A and 6 (Chutter, 1967: Table 11), and Site 1 (Chutter, 1963). The reference SASS5 Score is 182 and the ASPT is 6.1.

7.6.2 Baseline Description

Baseline biomonitoring data available for EWR 4 are summarised as follows:

Date	SASS5 Score	ASPT	No. of Taxa	Category (Dallas 2007)	MIRAI (%)	PES
11 - 04 - 08	120	6.7	18	B/C	61.7%	C/D
07 - 08 - 07	131	6.6	20	B/C		

7.6.3 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration, were recorded at the site during baseline sampling, and were selected as monitoring indicators for EWR 4.

Family	Flow				Substrate					Water Quality		
	Standing (<0.1 m/s)	Slow (0.1 - 0.3 m/s)	Mod (0.3 - 0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Vegetation	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7 - 10)	Low (SASS 4 - 6)
Heptageniidae (Flathead mayflies)		●	●	●		●	⬤	●		13		
Hydropsychidae (>2 spp)			●	⬤	●	⬤	●			12		
Baetidae (>2 spp)	●	●	⬤	⬤	●	●	⬤	●	●		10	
Leptophlebiidae (Prongills)	●	⬤	●		●	●	⬤	●	⬤		9	
Tricorythidae (Stout crawlers)			●	⬤	●	⬤	⬤	●			9	
Atyidae (Freshwater shrimps)		●						⬤			8	
Simuliidae (Blackflies)		●	⬤	⬤	⬤	⬤	⬤	⬤				5
Perlidae (Stoneflies)			●	⬤		●	⬤			12		
Psephenidae (Water pennies)			●	⬤		⬤	●				10	
Athericidae		●	⬤			●	⬤	●			10	
Elmiidae (Riffle beetles)			●	⬤		⬤	●	●			8	
Lestidae	●	●						⬤			8	
Ancylidae	●	●	●	●	●	●	●	●				6
Caenidae (Squaregills)	●	⬤				●	⬤	●	●			6
Hydropsychidae (2 spp)			●	⬤	●	⬤	●					5
Dytiscidae (Diving beetles)	⬤	●						⬤				5

● = Partial Preference ⬤ = Strong Preference

Two species of Flatheaded mayflies (Heptageniidae) were recorded at this site during baseline sampling. Caddisflies recorded included *Cheumatopsyche thomasseti, C. afra, Amphipysche scottae* and *Macrostenum capense.* The presence of Pale burrowers (Polymitarcyidae) was confirmed by empty shucks, but no live specimens were recorded.

7.6.4 EcoSpecs and TPCs relating to the MIRAI data: PES

EcoSpecs and TPCs for the PES at EWR 4 are provided below.

ECOSPECS: Biota	TPCS
SASS5 Score between 110 and 140.	SASS5 Score < 118.
ASPT between 6.2 and 6.8.	ASPT < 6.4.
MIRAI Score between 57% and 62%.	MIRAI Score < 59%.
Heptageniidae present.	Heptageniidae absent on two or more consecutive surveys.
Hydropsychidae > 2 spp present.	Hydropsychidae < 2 spp in two or more consecutive surveys.
Baetidae > 2 spp.	Baetidae < 2 spp.
Leptophlebiidae present.	Leptophlebiidae absent from two or more consecutive surveys.
Tricorythidae present (except winter).	Tricorythidae absent from two or more consecutive surveys (except winter).
Atyidae present.	Atyidae absent on two or more consecutive surveys.
Simuliidae present.	Simuliidae absent on two or more consecutive surveys.

8 EWR 5: SCANDANAVIA (VAAL RIVER)

A summary of the EcoClassification results are provided below (DWA, 2009c).

8.1 ECOCLASSIFICATION SUMMARY OF EWR 5

EWR 5: Scandinavia (Vaal River)

EIS: HIGH
Presence of rare and endangered *Labeobarbus kimberleyensis,* and Rand Highveld Grassveld vegetation type. Most importantly, this site falls within the Vredefort Dome World Heritage Site and the river is an important feature within this World Heritage Site.

PES: C/D
Combination of flow and non - flow related impacts. Flow related impacts include increased base flows and reduced frequency of moderate floods due to Vaal Dam and Barrage and releases to regulated TDS levels. Non - flow related impacts include agriculture, and urban sewage and industrial waste and the occurrence of gauges, weirs and dams in the system.

REC: C
Improvement of the PES due to **HIGH** EIS rating. A B/C EcoStatus could not be attained due to the limited operational possibilities from the Vaal Dam. Scenario includes decreased base flows for 3 days (during winter) (to improve macroinvertebrates EC) and increased moderate floods in the wet season.

AEC down: D
Increased base flows.
Possibility of further decrease of floods due to the development in tributaries and increased return flows.

IHI			Driver Components	PES Category	Trend	REC	AEC↓
INSTREAM	D	RIPARIAN D	HYDROLOGY	D		C/D	D
			WATER QUALITY	E	Negative	D/E	E
			GEOMORPHOLOGY	C	Negative	C	C/D
			Response Components	PES Category	Trend	REC	AEC↓
			FISH	C	Stable	B	D
			MACRO INVERTEBRATES	C	Stable	C	C/D
			INSTREAM	C		B/C	D
			RIPARIAN VEGETATION	D	Negative	C	-D
			ECOSTATUS	C/D		C	D

EcoSpecs and TPCs of EWR 5 are provided for the different components in Section 8.2 to 8.7.

8.2 GEOMORPHOLOGY

EcoSpecs and TPCs based on the GAI are provided in Section 8.2.1.

8.2.1 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Descriptor	EcoSpec	TPC
Bed material composition	All sediments here are clays, silts and fine sands, so no sediment sampling for the purposes of modelling potential bed material transport is required, and monitoring of bed material size is inappropriate for this site.	
		There should however be not riffles within the mainstream channel as this would indicate incision along the bed.
Channel morphology	There must be no further incision of the mainstem channel which might reduce overtopping frequencies. Incision of the channel can be monitored through resurveyed cross - sections.	
		Any deepening or widening of the channel at cross section scale.
	Using aerial photography, examine the reach for indications of levees or other restrictions (such as elevated roads and railways) across the floodplain, or for confinements (e.g. single culvert crossings). Such activities should be discouraged since they are likely to prevent recharge of floodplain wetlands and ox - bow lakes.	
	Any structures or levees in the reach which restrict flooding across the floodplain.	

8.3 PHYSICO - CHEMICAL VARIABLES

TPCs and EcoSpecs are provided in Section 8.3.1 – 8.3.2.

8.3.1 EcoSpecs relating to physico - chemical data: PES and REC

River: Vaal		EWR 5
Water quality metrics		**ECOSPEC: PES and REC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be ≤ 37 mg/L.
	Na_2SO_4	The 95th percentile of the data must be ≤ 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be ≤ 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be ≤ 21 mg/L.
	NaCl	The 95th percentile of the data must be ≤ 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be ≤ 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be ≤ 85 mS/m
	pH	The 5th and 95th percentiles of the data must range from 6.5 to 9.2.
	Temperature	Large season deviation from the natural temperature range.
	Dissolved oxygen	The 5th percentile of the data must be ≥ 6 mg/L.
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
Nutrients	TIN	The 50th percentile of the data must be ≤ 0.7 mg/L.
	PO_4 - P	The 50th percentile of the data must be ≤ 0.125 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be <30 µg/L.
	Chl - a periphyton	The 50th percentile of the data must be ≤ 84 mg/m^2.
	Toxics	The 95th percentile of the data must be within the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

8.3.2 TPCs relating to physico - chemical data

River: Vaal		EWR 5
Water quality metrics		**TPC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be 28 – 37 mg/L.
	Na_2SO_4	The 95th percentile of the data must be 16 – 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be 12 – 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be 17 – 21 mg/L.
	NaCl	The 95th percentile of the data must be 36 – 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be 280 – 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be < 85 mS/m.
	pH	The 5th and 95th percentiles of the data must be <6.5 and >9.2.
	Temperature	Initiate baseline monitoring for this variable.
	Dissolved oxygen	The 5th percentile of the data must be 7.8 – 7.5 mg/L.
Nutrients	TIN	The 50th percentile of the data must be 0.07 – 1.0 mg/L.
	PO_4 - P	The 50th percentile of the data must be > 0.125 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be >30 µg/L.
	Chl - a periphyton	The 50th percentile of the data must be 21-84 mg/m^2.
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

The upstream catchment patterns and natural sediments in the Vaal catchment are known to cause naturally large increases in sediment loads and turbidity (hence the system is known as the Vaal river system). Seasonally the habitat often silted but it is cleared from time to time when large floods come through this system. The dissolved oxygen and temperatures will be impacted by the Vaal Dam and the Vaal Barrage. These variables will increase due to warming in the Vaal Barrage. High nutrient and algal growth occur most of the year due to return flows from waste

water treatment works (WWTW) and urban runoff. Diurnal fluctuations are due to algal growth and releases from the Vaal Barrage. Turbidity highly variable due to releases from the Vaal Barrage but also settled by Barrage.

8.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the VEGRAI data are provided Section 8.4.1 to 8.4.2.

8.4.1 EcoSpecs and TPCs description relating to VEGRAI monitoring data: PES and REC

PES	REC	Assessed Component	Zone Assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Baseline Note
D	C	Exotic Invasion (perennial exotics).	Marginal zone.	Maintain perennial exotic species cover below 50%.	An increase in perennial exotic species above 50%.	Maintain perennial exotic species cover below 20%.	60 - 80%, severe *Eichornia* mainly, but also other non - woody exotics *(Eichornia* forming hydraulic control and affecting flow as well).
			Lower zone.	Maintain perennial exotic species cover below 50%.	An increase in perennial exotic species above 50%.	Maintain perennial exotic species cover below 20%.	60 - 80% mainly non - woody weeds replacing indigenous grasses, but *Salix babylonica, Senna didymobotrya* and *Sesbania* also occurred.
			Upper zone.	Maintain perennial exotic species cover below 50%.	An increase in perennial exotic species above 50%.	Maintain perennial exotic species cover below 20%.	60 - 80%, woody and non - woody, many dead exotic trees are coppicing.
		Terrestrial woody species cover.	Marginal zone.	Maintain cover of terrestrial woody species below 5%.	The presence of terrestrial woody species.	Maintain the absence of terrestrial woody species.	None recorded.
			Lower zone.	Maintain cover of terrestrial woody species below 20%.	An increase in woody terrestrial species covers above 10%.	Maintain cover of terrestrial woody species below 10%.	*Acacia karoo* recorded, about 5%.
			Upper zone.	Maintain cover of terrestrial woody species below 50%.	An increase in woody terrestrial species covers above 50%.	Maintain cover of terrestrial woody species below 30%.	40 - 60%.
		Indigenous Riparian Woody Cover.	Marginal zone.	Maintain indigenous riparian woody cover below 70%.	An absence of riparian woody cover OR an increase above 30%.	Maintain indigenous riparian woody cover below 50%, but retain presence i.e. not 0%.	< 10%, *S. mucronata.*
			Lower zone.	Maintain indigenous riparian woody cover below 50%.	An increase in riparian woody cover above 15%.	Maintain indigenous riparian woody cover below 30%.	< 10%, *S. mucronata.*
			Upper zone.	Maintain indigenous riparian woody cover below 40%.	An increase in riparian woody cover above 25%.	Maintain indigenous riparian woody cover below 25%.	Mostly terrestrial species acting as indicators of the riparian zone, 20%.
		Non - woody Indigenous Cover (grasses, sedges and dicotyledonous forbs).	Marginal zone.	Maintain non - woody cover above 10%, with sedges predominating.	A decrease in non - woody cover below 20%.	Maintain non - woody cover above 30%, with sedges predominating.	20 - 40%.
			Lower zone.	Maintain non - woody cover above 20%.	A decrease in non - woody cover below 40%.	Maintain non - woody cover above 40%.	40 - 60%.
			Upper zone.	Maintain a presence of non - woody cover.	A decrease in non - woody cover below 20%.	Maintain non - woody cover above 20%.	20 – 40%.
		Phragmites (reed) cover.	Riparian zone.	Maintain the absence of reeds.	A presence of reeds.	Maintain the absence of reeds.	Reeds were not recorded on the site although they did occur in localised beds higher upstream on a mid - channel bar.

8.4.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data

Colour coding in the table below refers to:

EcoSpecs	TPC	Baseline	PES	REC

EC	Perennial Exotics (%)	Terrestrialization (%)	Riparian Woody (%)	Non-woody (%)	Reeds (%)
Marginal Zone					
A	0	0	5 - 10	70 - 80	0
A/B	1 - 5	0	10 - 20	60 - 70; 80 - 90	0
B	5 - 10	0	1 - 5; 20 - 30	50 - 60; >90	0
B/C	10 - 15	0	30 - 40	40 - 50	0
C	15 - 20	0	40 - 50	30 - 40	0
C/D	20 - 30	0	0; 50 - 60	20 - 30	1 - 5
D	30 - 50	1 - 5	60 - 70	10 - 20	5 - 10
D/E	50 - 60	5 - 10	70 - 80	1 - 10	10 - 15
E	60 - 70	10 - 15	80 - 90	0	15 - 20
E/F	70 - 80	15 - 20	>90		20 - 25
F	>80	>20			>25
Lower Zone					
A	0	0	0 - 5	80 - 90	0
A/B	1 - 5	0	5 - 10	70 - 80; >90	0
B	5 - 10	0	10 - 15	60 - 70	0
B/C	10 - 15	1 - 5	15 - 20	50 - 60	0
C	15 - 20	5 - 10	20 - 30	40 - 50	0
C/D	20 - 30	10 - 15	30 - 40	30 - 40	1 - 10
D	30 - 50	15 - 20	40 - 50	20 - 30	10 - 20
D/E	50 - 60	20 - 30	50 - 60	10 - 20	20 - 30
E	60 - 70	30 - 40	60 - 70	5 - 10	30 - 40
E/F	70 - 80	40 - 50	70 - 80	1 - 5	40 - 50
F	>80	>50	>80		>50
Upper Zone					
A	0	0 - 5	0 - 5	80 - 90	0
A/B	1 - 5	5 - 10	5 - 10	70 - 80; >90	0
B	5 - 10	10 - 15	10 - 15	50 - 70	0
B/C	10 - 15	15 - 20	15 - 20	30 - 50	0
C	15 - 20	20 - 30	20 - 25	20 - 30	0
C/D	20 - 30	30 - 40	25 - 30	1 - 20	0
D	30 - 50	40 - 50	30 - 40	0	1 - 5
D/E	50 - 60	50 - 60	40 - 50		5 - 10
E	60 - 70	60 - 70	50 - 60		10 - 15
E/F	70 - 80	70 - 80	60 - 70		15 - 20
F	>80	>80	>70		>20

8.5 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 8.5.1. The spatial FROC of EWR 5 is provided in Section 8.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

8.5.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp	PES					REC
			EWR SITE		REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
3	Species richness.	All indigenous species.	Eight of an expected 11 species to be sampled (as per 2 EWR baseline surveys).	Less than five fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity - depth categories and cover features (to be quantified by RHAM).	All indigenous species.	Baseline (PES) FRAI score of 69.2% (C) calculated for the reach. Any decreased FROC in reach of especially ASCL, BAEN and LCAP (refer to FROC: Table 2[1]) OR FRAI scores decreasing below 62,02% (category C/D).	An improvement from PES FROC in the reach for especially ASCL, BTRI, BANO, and LUMB should be indicative of reaching/ maintaining the REC (refer To FROC sheet for more detail).
3	Relative abundance.	All indigenous species.	Fish sampled at > 0.44 individuals per minute (electrofishing).	Relative abundance of less than 0.3 individual per minute sampled at the site (during same season as baseline data) when habitat can be sampled efficiently using electrofishing.	N/A	N/A	N/A	
4	Alien fish species.	Any alien/introduced spp.	Two alien fish species sampled at site 100% of time. CCAR at < 0.012 indiv/min and GAFF at < 1.26 indiv/min.	CCAR sampled at > 0.02, and GAFF at > 2 indiv/min. Sampling of any alien/introduced fish species at site other than CCAR and GAFF during any survey.	N/A	Any alien/introduced spp.	Increase in the number of alien species (> 4 species in reach) OR presence of any alien species other than CCAR, GAFF, MSAL and CIDE.	
1	FD habitats, substrate, flow dependant spp (flow alteration), water quality intolerance, SD habitats, water column.	BAEN, LCAP	BAEN and LCAP sampled 100% of the time. BAEN present at relative abundance of > 0.04 indiv/min and LCAP sampled at relative abundance of > 0.12 indiv/min.	BAEN and LCAP present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.02 indiv/min for BAEN and < 0.08 indiv/min for LCAP.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows), Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates. To be quantified with RHAM. Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools), Reduction in suitability of water column (i.e. increased sedimentation of pools).	BAEN LCAP	Any decreased FROC in reach of BAEN and LCAP (refer to FROC, column F: Table 2).	
1	FS habitats.	BAEN	BAEN sampled 100% of the time. BAEN present at relative abundance of > 0.04 indiv/min.	BAEN present less than 100% of time (not sampled during any survey) AND/OR decrease in relative abundance of < 0.02 indiv/min.	Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows), to be quantified with RHAM.	BAEN ASCL	Any decreased FROC in reach of BAEN and ASCL (refer to FROC, column F: Table 2).	
4	SS habitats, overhanging vegetation.	PPHI, TSPA	PPHI and TSPA sampled 100% of time. PPHI present at relative abundance of > 0.21 indiv/min. and TSPA sampled at relative abundance of > 0.01	PPHI and TSPA present less than 100% of time (not sampled during any survey), AND/OR decrease in relative abundance of PPHI < 0.1 indiv/min, and TSPA < 0.005.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats). To be quantified with RHAM. Significant change in overhanging	PPHI TSPA	Any decreased FROC in reach of PPHI and TSPA (refer to FROC, column F: Table 2).	

Rank	Metric	Indicator spp	PES						REC
			EWR SITE		REACH				REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
			indiv/min.		vegetation habitats (to be quantified with RHAM).				
2	Undercut banks.	PPHI	PPHI sampled 100% of time, present at relative abundance of > 0.21 indiv/min.	PPHI present less than 100% of time (not sampled during any survey), AND/OR decrease in relative abundance of < 0.1 indiv/min.	Significant change in undercut bank habitats (to be quantified with RHAM).	ASCL	PPHI	Any decreased FROC in reach of ASCL and PPHI (refer to FROC, column F: Table 2).	
2	Instream vegetation.	TSPA	TSPA sampled 100% of time, and sampled at relative abundance of > 0.01 indiv/min.	TSPA present less than 100% of time (not sampled during any survey), AND/OR decrease in relative abundance of < 0.005 indiv/min.	Significant change in overhanging vegetation habitats (to be quantified with RHAM).	BPAU	TSPA	Any decreased FROC in reach of BPAU and TSPA (refer to FROC, column F: Table 2).	

1 Refer to DWA (2010a).

8.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (C)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
ASCL	*Austroglanis sclateri* (Boulenger, 1901)	3	1	0	2
BAEN	***Labeobarbus aeneus* (Burchell, 1822)**	**5**	**5**	**4**	**5**
BANO	*Barbus anoplus* (Weber, 1897)	2	1	0	2
BKIM	***Labeobarbus kimberleyensis* (Gilchrist and Thompson, 1913)**	**3**	**2**	**1**	**2**
BPAU	*Barbus paludinosus* (Peters, 1852)	3	2	1	2
BTRI	***Barbus trimaculatus* (Peters, 1852)**	**3**	**1**	**0**	**2**
CGAR	***Clarias gariepinus* (Burchell, 1822)**	**3**	**3**	**2**	**3**
LCAP	***Labeo capensis* (Smith, 1841)**	**5**	**5**	**4**	**5**
LUMB	***Labeo umbratus* (Smith, 1841)**	**3**	**2**	**1**	**3**
PPHI	***Pseudocrenilabrus philander* (Weber, 1897)**	**3**	**3**	**2**	**3**
TSPA	***Tilapia sparrmanii* (Smith, 1840)**	**3**	**3**	**2**	**3**
(species in bold sampled at EWR site during baseline surveys)					

8.6 MACROINVERTEBRATES

8.6.1 Reference Conditions

There are no historical data from near this site. Reference conditions are based on professional judgment and data collected by Dr Mark Chutter from his Site 15 (Chutter, 1963). The reference SASS5 Score is 175 and the ASPT is 6.7.

8.6.2 Baseline Description

Baseline biomonitoring data available for EWR 5 are summarised as follows:

Date	SASS5 Score	ASPT	No. of Taxa	Category (Dallas 2007)	MIRAI (%)	PES
11 - 04 - 08	102	6.0	17	C	71.0%	C
06 - 08 - 07	103	5.4	19	C		

8.6.3 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration, were recorded at the site during baseline sampling, and were selected as monitoring indicators for EWR 5.

Family	Flow				Substrate					Water Quality		
	Standing (<0.1 m/s)	Slow (0.1 - 0.3 m/s)	Mod (0.3 - 0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Vegetation	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7 - 10)	Low (SASS 4 - 6)
Hydropsychidae (>2 spp)			●	⬤	●	⬤	●			12		
Baetidae (>2 spp)	●	●	⬤	⬤	●	●	⬤	●	●		10	
Leptophlebiidae (Prongills)	●	⬤	●	⬤	●	●	⬤	●	⬤		9	
Tricorythidae (Stout crawlers)			●	⬤	●	⬤	⬤	●			9	
Atyidae (Freshwater shrimps)		●						⬤			8	
Simuliidae (Blackflies)		●	⬤	⬤	⬤	⬤	⬤	⬤				5
Heptageniidae (Flathead mayflies)		●	●	●		●	⬤	●		13		
Perlidae (Stoneflies)			●	⬤		●	⬤			12		
Psephenidae (Water pennies)			●	⬤		⬤	●				10	
Athericidae		●	⬤			●	⬤	●			10	
Elmiidae (Riffle beetles)			●	⬤		⬤	●	●			8	
Lestidae	●	●						⬤			8	
Ancylidae	●	●	●	●	●	●	●	●				6
Caenidae (Squaregills)	●	⬤				●	⬤	●	●			6
Hydropsychidae (2 spp)			●	⬤	●	⬤	●					5
Dytiscidae (Diving beetles)	⬤	●						⬤				5

● = Partial Preference ⬤ = Strong Preference

Caddisflies recorded at the site during baseline sampling included *Cheumatopsyche thomasseti, C. afra, Amphipysche scottae* and *Macrostenum capense.* Blackflies recorded at the site during baseline conditions were *Simulium adersi* and *S. damnosum*, both potential pest species of poultry and livestock respectively. Freshwater shrimps (Atyidae) were noticeably absent.

8.6.4 EcoSpecs and TPCs relating to the MIRAI data: PES and REC

EcoSpecs and TPCs for the PES and REC (C) at EWR 5 are provided below:

ECOSPECS: Biota	TPCS
SASS5 Score between 88 and 118.	SASS5 Score < 95.
ASPT between 5.4 and 6.0.	ASPT < 5.6.
MIRAI Score between 62% and 77%.	MIRAI Score < 64%.
To ensure that no group consistently dominates the fauna, defined as C abundance (> 100) over two consecutive surveys.	Any taxon abundance 'D' (> 1000) in two consecutive surveys.
Hydropsychidae > 2 spp present: Overall abundance > A.	Hydropsychidae < 2 spp in two or more consecutive surveys; Overall abundance < B.
Baetidae > 2 spp.	Baetidae < 2 spp.
Leptophlebiidae present.	Leptophlebiidae absent from two or more consecutive surveys.
Tricorythidae present (except winter).	Tricorythidae absent from two or more consecutive surveys (except winter).
Atyidae present.	Atyidae absent on two or more consecutive surveys.
Simuliidae present.	Simuliidae absent on two or more consecutive surveys.

9 EWR 6: KLIP (KLIP RIVER)

A summary of the EcoClassification results are provided below (DWA, 2009c).

9.1 ECOCLASSIFICATION SUMMARY OF EWR 6

EWR 6 Klip (Klip River)

EIS: MODERATE
PES: B/C
Combination of flow and non - flow related impacts. Flow related impacts include reduced base flows and moderate floods due to weirs and farm dams. Non - flow related impacts include agriculture, cattle grazing, and alien vegetation. The sole reason for the PES not being a B EcoStatus is the current vegetation EC (B/C EC) due to the high proportion of exotic species

REC: B/C
The EIS at EWR 6 is **MODERATE** and the REC is to maintain the PES.

AEC up: B
A B EC can be achieved by removal of alien vegetation. Improving flows will not improve the vegetation.

AEC down: C
The scenario includes decreased low flows and zero flows and decreased moderate floods and deteriorated water quality.

Driver Components	PES and REC Category	Trend	AEC ↓
HYDROLOGY	C		
WATER QUALITY	B/C	Negative	C
GEOMORPHOLOGY	B	Stable	C
Response Components	**PES Category**	**Trend**	**AEC↓**
FISH	B	Stable	C
MACRO INVERTEBRATES	B	Stable	C
INSTREAM	B		C
RIPARIAN VEGETATION	B/C	Stable	C
ECOSTATUS	B/C		C

EcoSpecs and TPCs are provided for the different components in Section 9.2 to 9.7.

9.2 GEOMORPHOLOGY

EcoSpecs and TPCs based on the GAI are provided in Section 9.2.1.

9.2.1 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Descriptor	EcoSpec	TPC
Bed material composition	Sampling of the dry season bed material at the EWR site (using a sample size of not less than 500 points) should be undertaken at the prescribed intervals (every 5 years) to assess impacts of flow on the bed sediment and therefore as an indication of the change of available habitat for instream biota. Fining of the bed (i.e. decreases in the size of the 16th, 50th and 84th percentiles of the sediment size distribution as indicated to the left) would indicate insufficient flows being delivered to the site to maintain the geomorphological condition.	
	D_{16} = 18 mm	D_{16} sediment size must be greater than 10 mm
	D_{50} = 120 mm	D_{50} sediment size must be greater than 100 mm
	D_{84} = 250 mm	D_{84} sediment size must be greater than 200 mm
Channel morphology	This site is located within dolerites and therefore the morphology of the site is extremely insensitive to flow modifications. Therefore ***monitoring of the cross - section at this site is not required.***	

9.3 PHYSICO - CHEMICAL VARIABLES

TPCs and EcoSpecs are provided in Section 9.3.1 – 9.3.2.

9.3.1 EcoSpecs relating to physico - chemical data: PES and REC

River: Vaal		EWR 6
Water quality metrics		**EcoSpecs: PES and REC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be < 16 mg/L
	Na_2SO_4	The 95th percentile of the data must be < 20 mg/L
	$MgCl_2$	The 95th percentile of the data must be < 15 mg/L
	$CaCl_2$	The 95th percentile of the data must be < 21 mg/L
	NaCl	The 95th percentile of the data must be < 45 mg/L
	$CaSO_4$	The 95th percentile of the data must be 280 – 351 mg/L
Physical variables	EC	The 95th percentile of the data must be < 55 mS/m
	pH	The 5th and 95th percentiles of the data must be between 6.00 – 6.24 and 8.37 – 8.69
	Temperature	Initiate baseline monitoring for this variable if Level II or higher of the DSS
	Dissolved oxygen	Must be between 7 and 8 mg/L.
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable
Nutrients	TIN	The 50th percentile of the data must be <0.25 mg/L
	PO_4 - P	The 50th percentile of the data must be > 0.02 mg/L
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be between 10 and 15 µg/L
	Chl - a periphyton	The 50th percentile of the data must be 1.7 to 12 mg/m^2
	Toxics	The 95th percentile of the data must be within the TWQR as stated in DWAF (1996)

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

9.3.2 TPCs relating to physico - chemical data

River: Vaal		EWR 6
Water quality metrics		**TPC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be < 16 mg/L
	Na_2SO_4	The 95th percentile of the data must be < 20 mg/L
	$MgCl_2$	The 95th percentile of the data must be < 15 mg/L
	$CaCl_2$	The 95th percentile of the data must be < 21 mg/L
	NaCl	The 95th percentile of the data must be < 45 mg/L
	$CaSO_4$	The 95th percentile of the data must be 280 – 351 mg/L
Physical variables	EC	The 95th percentile of the data must be < 55 mS/m
	pH	The 5th and 95th percentiles of the data must be between 6.00 – 6.24 and 8.37 – 8.69
	Temperature	Initiate baseline monitoring for this variable if Level II or higher of the DSS
	Dissolved oxygen	Must be between 7 and 8 mg/L.
Nutrients	TIN	The 50th percentile of the data must be <0.25 mg/L
	PO_4 - P	The 50th percentile of the data must be > 0.02 mg/L
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be between 10 and 15 µg/L
	Chl - a periphyton	The 50th percentile of the data must be 1.7 to 12 mg/m^2
	Toxics	An impact is expected if the 95th percentile of the data exceeds the TWQR as stated in DWAF (1996)

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

9.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the VEGRAI data are provided Section 9.4.1 to 9.4.2.

9.4.1 EcoSpecs and TPCs description relating to VEGRAI monitoring data: PES and REC

PES and REC	Assessed Component	Zone Assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Baseline Note
B/C	Exotic Invasion (perennial exotics).	Marginal zone.	Maintain perennial exotic species cover below 15%.	An increase in perennial exotic species above 5%.	Same as PES	< 10% recorded during VEGRAI assessment; mostly non - perennial weeds but *S. babylonica* occurred.
		Lower zone.	Maintain perennial exotic species cover below 15%.	An increase in perennial exotic species above 15%.		20 - 40% recorded during VEGRAI assessment with about 15% being perennial exotics (*S. babylonica*).
		Upper zone.	Maintain perennial exotic species cover below 15%.	An increase in perennial exotic species above 10%.		40 - 60%, high impact on grasses, non - woody weeds mainly but *Pyracantha* about 10%.
	Terrestrial woody species cover.	Marginal zone.	Maintain the absence of terrestrial woody species.	The presence of terrestrial woody species.		No woody terrestrial species were recorded.
		Lower zone.	Maintain cover of terrestrial woody species below 5%.	The presence of terrestrial woody species.		No woody terrestrial species were recorded.
		Upper zone.	Maintain cover of terrestrial woody species below 20%.	An increase in woody terrestrial species covers above 20%.		About 20% of woody species recorded.
	Indigenous Riparian Woody Cover.	Marginal zone.	Maintain indigenous riparian woody cover below 40%, but retain presence i.e. not 0%.	An absence of riparian woody cover OR an increase above 30%.		< 5%, only *Gomphostigma virgatum* recorded.
		Lower zone.	Maintain indigenous riparian woody cover below 20%.	An increase in riparian woody cover above 10%.		0% recorded.
		Upper zone.	Maintain indigenous riparian woody cover below 20%.	An increase in riparian woody cover above 20%.		20%, *Leucosidea sericea* mainly.
	Non - woody Indigenous Cover (grasses, sedges and dicotyledonous forbs).	Marginal zone.	Maintain non - woody cover above 40%, with sedges predominating.	A decrease in non - woody cover below 40%.		40 - 60% recorded during VEGRAI assessment.
		Lower zone.	Maintain non - woody cover above 50%.	A decrease in non - woody cover below 50%.		40 - 60% recorded during VEGRAI assessment.
		Upper zone.	Maintain non - woody cover above 30%, with grasses predominating.	A decrease in non - woody cover below 30%.		40 - 60% recorded during VEGRAI assessment.
	Phragmites (reed) cover.	Riparian zone.	Maintain the absence of reeds.	A presence of reeds.		Reeds were not observed at the site, and are not expected.

9.4.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data: PES and REC

Colour coding in the table below refers to:

EcoSpecs	TPC	Baseline	PES and REC

Class	Perennial Exotics (%)	Terrestrialization (%)	Riparian Woody (%)	Non-woody (%)	Reeds (%)
Marginal Zone					
A	0	0	5 - 10	70 - 80	0
A/B	1 - 5	0	10 - 20	60 - 70 ; 80 - 90	0
B	5 - 10	0	1 - 5 ; 20 - 30	50 - 60; > 90	0
B/C	10 - 15	0	30 - 40	40 - 50	0

Class	Perennial Exotics (%)	Terrestrialization (%)	Riparian Woody (%)	Non-woody (%)	Reeds (%)
C	15 - 20	0	40 - 50	30 - 40	0
C/D	20 - 30	0	0 ; 50 - 60	20 - 30	1 - 5
D	30 - 50	1 - 5	60 - 70	10 - 20	5 - 10
D/E	50 - 60	5 - 10	70 - 80	1 - 10	10 - 15
E	60 - 70	10 - 15	80 - 90	0	15 - 20
E/F	70 - 80	15 - 20	> 90		20 - 25
F	> 80	> 20			> 25
Lower Zone					
A	0	0	0 - 5	80 - 90	0
A/B	1 - 5	0	5 - 10	70 - 80; > 90	0
B	5 - 10	0	10 - 15	60 - 70	0
B/C	10 - 15	1 - 5	15 - 20	50 - 60	0
C	15 - 20	5 - 10	20 - 30	40 - 50	0
C/D	20 - 30	10 - 15	30 - 40	30 - 40	1 - 10
D	30 - 50	15 - 20	40 - 50	20 - 30	10 - 20
D/E	50 - 60	20 - 30	50 - 60	10 - 20	20 - 30
E	60 - 70	30 - 40	60 - 70	5 - 10	30 - 40
E/F	70 - 80	40 - 50	70 - 80	1 - 5	40 - 50
F	> 80	> 50	> 80		> 50
Upper Zone					
A	0	0 - 5	0 - 5	80 - 90	0
A/B	1 - 5	5 - 10	5 - 10	70 - 80; > 90	0
B	5 - 10	10 - 15	10 - 15	50 - 70	0
B/C	10 - 15	15 - 20	15 - 20	30 - 50	0
C	15 - 20	20 - 30	20 - 25	20 - 30	0
C/D	20 - 30	30 - 40	25 - 30	1 - 20	0
D	30 - 50	40 - 50	30 - 40	0	1 - 5
D/E	50 - 60	50 - 60	40 - 50		5 - 10
E	60 - 70	60 - 70	50 - 60		10 - 15
E/F	70 - 80	70 - 80	60 - 70		15 - 20
F	>80	>80	>70		>20

9.5 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 9.5.1. The spatial FROC of EWR 6 is provided in Section 9.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

9.5.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES					REC
			EWR SITE		REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
6	Species richness.	All indigenous species.	Three of an expected 5 indigenous fish species to be sampled (as per EWR baseline surveys).	Less than four species sampled during any survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity - depth categories and cover features (to be quantified by RHAM if applicable).	All indigenous species.	Baseline (PES) FRAI score of 82.2% (low B) calculated for the reach. Any decreased FROC in reach of especially BAEN and LCAP (refer to FROC: Table 2[1]) **OR** FRAI scores decreasing below 77.4 % (category C).	Same as PES.
5	Relative abundance.	All indigenous species.	Fish sampled at > 0.8 individuals per minute (electrofishing).	Relative abundance of less than 0.6 individual per minute sampled at the site (during same seasons as baseline data) when habitat can be sampled efficiently using electrofishing.	N/A	N/A	N/A	
7	Alien fish species.	Any alien/introduced spp.	No alien fish species.	Presence of any alien/introduced fish species at site during any survey.	N/A	Any alien/introduced spp.	Presence of any alien/introduced fish species in reach during any survey.	
1	FD Habitats, flow dependant spp (flow alteration), water column, FS habitats.	LCAP	LCAP sampled 100% of time (50% using electrofishing at relative abundance of 0.01 indiv/min).	LCAP present less than 50% of time when only conducting electrofishing **AND/OR** decrease in relative abundance of < 0.01 indiv/min.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows), Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools), Reduction in suitability of water column (i.e. increased sedimentation of pools). To be quantified with RHAM.	LCAP BAEN	Any decreased FROC in reach of LCAP and BAEN (refer to FROC, column F: Table 2).	
2	Substrate.	LCAP, LUMB	LCAP sampled 100% of time (50% using electrofishing at relative abundance of 0.01 indiv/min). LUMB sampled 50% of time (only through using of gillnets).	LCAP present less than 50% of time when only conducting electrofishing **AND/OR** decrease in relative abundance of < 0.01 indiv/min (electrofishing). LUMB present less than 50% of time when using gillnets during 2 consecutive surveys.	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates. To be quantified with RHAM.	LCAP LUMB	Any decreased FROC in reach of LCAP and LUMB (refer to FROC, column F: Table 2).	
3	Water quality intolerance, SD habitats.	LCAP, BANO	LCAP sampled 100% of time (50% using electrofishing at relative abundance of 0.01 indiv/min). BANO sampled 100% of times at a relative abundance of > 0.9	LCAP present less than 50% of time when only conducting electrofishing **AND/OR** decrease in relative abundance of < 0.01 indiv/min (electrofishing). BANO present less than 100% of time	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools). To be quantified with RHAM. Decreased water quality (as indicated by PAI,	BPAL LCAP	Any decreased FROC in reach of BPAL and LCAP (refer to FROC, column F: Table 2).	

Rank	Metric	Indicator spp.	PES						REC
			EWR SITE		REACH				REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
			indiv/min.	(absent during any survey) or present at relative abundance < 0.5 indiv/min.	RHAM visual, or water quality assessments).				
4	SS habitats, overhanging and instream vegetation.	BANO	BANO sampled 100% of times at a relative abundance of > 0.9 indiv/min.	BANO present less than 100% of time (absent during any survey) or present at relative abundance < 0.5 indiv/min.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats). To be quantified with RHAM.	BANO	BPAL	Any decreased FROC in reach of BANO and BPAL (refer to FROC, column F: Table 2).	
8	Undercut banks.	No indicator species of undercut banks expected/present at site or reach.							

1 Refer to electronic data (DWA, 2010a).

9.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (B)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
BAEN	*Labeobarbus aeneus* (Burchell, 1822)	2	1	0	Same as PES
BANO	***Barbus anoplus* (Weber, 1897)**	**3**	**3**	**2**	
BPAL	*Barbus pallidus* (Smith, 1841)	2	1	0	
LCAP	***Labeo capensis* (Smith, 1841)**	**3**	**3**	**2**	
LUMB	***Labeo umbratus* (Smith, 1841)**	**2**	**2**	**1**	
(species in bold sampled at EWR site during baseline surveys)					

9.6 MACROINVERTEBRATES

9.6.1 Reference Conditions

Reference conditions are based on professional judgment and data collected by Dr Mark Chutter from his Sites 26 (this site) and 8 (Chutter, 1967: Table 11). The reference SASS5 Score is 205 and the ASPT is 6.8.

9.6.2 Baseline Description

Baseline biomonitoring data available for EWR 6 are summarised as follows:

Date	SASS5 Score	ASPT	No. of Taxa	Category (Dallas 2007)	MIRAI (%)	PES
08 - 04 - 08	169	5.6	30	A/B	86.5%	B
18 - 09 - 07	173	6.2	28	A		

9.6.3 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration, were recorded at the site during baseline sampling, and were selected as monitoring indicators for EWR 6.

Family	Flow				Substrate					Water Quality		
	Standing (<0.1 m/s)	Slow (0.1 - 0.3 m/s)	Mod (0.3 - 0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Vegetation	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7 - 10)	Low (SASS 4 - 6)
Heptageniidae (Flathead mayflies)		●	●	●		●	●	●		13		
Hydropsychidae (>2 spp)			●	●	●	●	●			12		
Perlidae (Stoneflies)			●	●		●	●			12		
Baetidae (>2 spp)	●	●	●	●	●	●	●	●	●		10	
Psephenidae (Water pennies)			●	●		●	●				10	

Family	Flow				Substrate					Water Quality		
	Standing (<0.1 m/s)	Slow (0.1 - 0.3 m/s)	Mod (0.3 - 0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Vegetation	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7 - 10)	Low (SASS 4 - 6)
Leptophlebiidae (Prongills)	●	⬤	●		●	●	⬤	●	⬤		9	
Athericidae		●	⬤			●	⬤	●			10	
Tricorythidae (Stout crawlers)			●	⬤	●	⬤	⬤	●			9	
Atyidae (Freshwater shrimps)		●						⬤			8	
Elmiidae (Riffle beetles)			●	⬤		⬤	●	●			8	
Lestidae	●	●						⬤			8	
Ancylidae	●	●	●	●	●	●	●	●				6
Caenidae (Squaregills)	●	⬤				●	⬤	●	●			6
Hydropsychidae (2 spp)			●	⬤	●	⬤	●					5
Simuliidae (Blackflies)		●	⬤	⬤	⬤	⬤	⬤	⬤				5
Dytiscidae (Diving beetles)	⬤	●						⬤				5

● = Partial Preference ⬤ = Strong Preference

The fauna recorded at the site is typical of unpolluted, lower foothill streams, and included Stoneflies (Perlidae), Water pennies (Psephenidae), Brushlegged mayflies (Oligoneuridae), and Pale Burrowers (Polymitarcyidae). The large and characteristic mayfly *Centroptiloides bifasciata* was recorded. Caddisflies recorded at the site during baseline sampling included *Cheumatopsyche thomasseti, C. afra, Amphipysche scottae* and *Macrostenum capense.* The site also supported freshwater sponge and Sisyridae, which feed exclusively on sponges. Three families of bivalve were recorded at the site (Sphaeridae, Unionidae and Corbiculidae), although only one of these was found alive (Sphaeridae).

9.6.4 EcoSpecs and TPCs relating to the MIRAI data: PES and REC

EcoSpecs and TPCs for the PES and REC (B) at EWR 6 are provided below.

ECOSPECS: Biota	TPCS
SASS5 Score between 156 and 186.	SASS5 Score < 163.
ASPT between 5.5 and 6.2.	ASPT < 5.6.
MIRAI Score between 82% and 87%.	MIRAI Score < 83%.
To ensure that no group consistently dominates the fauna, defined as C abundance (> 100) over two consecutive surveys.	Any taxon abundance 'D' (> 1000) in two consecutive surveys.
Heptageniidae present.	Heptageniidae absent on two or more consecutive surveys.
Hydropsychidae > 2 spp present: Overall abundance > A.	Hydropsychidae < 2 spp in two or more consecutive surveys; Overall abundance < B.
Baetidae > 2 spp.	Baetidae < 2 spp.
Perlidae present.	Perlidae absent from two or more consecutive surveys.
Psephenidae present.	Psephenidae absent from two or more consecutive surveys.
Leptophlebiidae present.	Leptophlebiidae absent from two or more consecutive surveys.

10 EWR 7: UPPER WILGE (WILGE RIVER)

A summary of the EcoClassification results are provided below (DWA, 2009c).

10.1 ECOCLASSIFICATION SUMMARY OF EWR 7

EWR 7 Upper Wilge (Wilge River)

EIS : HIGH
There are rare and endangered species i.e. the flufftail crowned crane, bald ibis, and 11 red data vegetation species. There is a good diversity of habitats that include wetlands, flood plains, oxbow lakes and peat lands.

PES: A/B
Non - flow related impacts that include small dams for agriculture and exotic fish species (MSAL).

REC A/B
As the PES is also relatively high, the attainable and realistic objective is to maintain the PES even though a **HIGH** EIS would normally warrant improvement.

AEC Down: C
The scenario includes decreased low flows, some periods of zero flows and decreased moderate floods.

Driver Components	PES and REC Category	Trend	AEC↓
HYDROLOGY	A		
WATER QUALITY	B	Negative B/C	-B
GEOMORPHOLOGY	A	Negative B/C	B/C
Response Components	**PES Category**	**Trend**	**AEC↓**
FISH	B (D)	Negative D/E	C
MACRO INVERTEBRATES	B	Stable	C/D
INSTREAM	B		C
RIPARIAN VEGETATION	A/B	Stable	B/C
ECOSTATUS	A/B		C

EcoSpecs and TPCs are provided for the different components in Section 10.2 to 10.7.

10.2 GEOMORPHOLOGY

EcoSpecs and TPCs based on the GAI are provided in Section 10.2.1.

10.2.1 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Descriptor	EcoSpec	TPC
Bed material composition	All sediments here are clays, silts and fine sands, so no sediment sampling for the purposes of modelling potential bed material transport is required, and monitoring of bed material size is inappropriate for this site.	
		There should however be not riffles within the mainstream channel as this would indicate incision along the bed.
Channel morphology	There must be no further incision of the mainstem channel which might reduce overtopping frequencies. Incision of the channel can be monitored through resurveyed cross - sections.	
		Any deepening or widening of the channel at cross section scale.
	Using aerial photography, examine the reach for indications of levees or other restrictions (such as elevated roads and railways) across the floodplain, or for confinements (e.g. single culvert crossings). Such activities should be discouraged since they are likely to prevent recharge of floodplain wetlands and ox - bow lakes.	
	Any structures or levees in the reach which restrict flooding across the floodplain.	

10.3 PHYSICO - CHEMICAL VARIABLES

TPCs and EcoSpecs are provided in Section 10.3.1 – 10.3.2.

10.3.1 EcoSpecs relating to physico - chemical data: PES and REC

River: Vaal		EWR 7
Water quality metrics		**EcoSpecs: PES and REC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be < 20 mg/L.
	Na_2SO_4	The 95th percentile of the data must be < 15 mg/L.

River: Vaal		EWR 7
Water quality metrics		**EcoSpecs: PES and REC**
	$MgCl_2$	The 95th percentile of the data must be < 21 mg/L.
	$CaCl_2$	The 95th percentile of the data must be < 45 mg/L.
	NaCl	The 95th percentile of the data must be< 351 mg/L.
	$CaSO_4$	The 95th percentile of the data must be 280 – 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be < 55 mS/m.
	pH	The 5th and 95th percentiles of the data must be between > 5.9 and < 9.2.
	Temperature	Initiate baseline monitoring for this variable.
	Dissolved oxygen	Must be between 7 and 8 mg/L.
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
Nutrients	TIN	The 50th percentile of the data must be between < 4 mg/L.
	PO_4 - P	The 50th percentile of the data must be between < 0.125 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be between 10 and 15 µg/L.
	Chl - a periphyton	The 50th percentile of the data must be between 1.7 to 12 mg/m^2.
	Toxics	An impact is expected if the 95th percentile of the data exceeds the TWQR as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

10.3.2 TPCs relating to physico - chemical data

River: Vaal		EWR 7
Water quality metrics		**TPC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be < 16 mg/L.
	Na_2SO_4	The 95th percentile of the data must be < 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be < 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be < 21 mg/L.
	NaCl	The 95th percentile of the data must be < 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be 280 – 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be < 55 mS/m.
	pH	The 5th and 95th percentiles of the data must be between 5.9 – 6.4 and 8.8 – 9.2.
	Temperature	Initiate baseline monitoring for this variable.
	Dissolved oxygen	Must be between 7 and 8 mg/L.
Nutrients	TIN	The 50th percentile of the data must be between 1 and 4 mg/L.
	PO_4 - P	The 50th percentile of the data must be between < 0.125 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be between 10 and 15 µg/L.
	Chl - a periphyton	The 50th percentile of the data must be 1.7 to 12 mg/m^2.
	Toxics	An impact is expected if the 95th percentile of the data exceeds the TWQR as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

10.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the VEGRAI data are provided Section 10.4.1 to 10.4.2.

10.4.1 EcoSpecs and TPCs description relating to VEGRAI monitoring data: PES and REC

PES and REC	Assessed Component	Zone Assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Baseline Note
A/B	Exotic Invasion (perennial exotics).	Marginal and Lower zones.	Maintain perennial exotic species cover below 5%.	An increase in perennial exotic species above 10%.	Same as PES	< 10%, minor impact by herbaceous weeds, also woody non - aggressive component.

PES and REC	Assessed Component	Zone Assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Baseline Note
		Lower zone.	Maintain perennial exotic species cover below 5%.	An increase in perennial exotic species above 10%.		< 10%, minor impact by herbaceous weeds, also woody non - aggressive component.
		Upper zone.	Maintain perennial exotic species cover below 5%.	A presence of perennial exotic species.		< 10%, non - woody weeds in grasslands.
	Terrestrial woody species cover.	Marginal zone.	Maintain the absence of terrestrial woody species.	The presence of terrestrial woody species.		No woody terrestrial species were recorded.
		Lower zone.	Maintain the absence of terrestrial woody species.	The presence of terrestrial woody species.		No woody terrestrial species were recorded.
		Upper zone.	Maintain cover of terrestrial woody species below 10%.	An increase in woody terrestrial species covers above 10%.		< 5%.
	Indigenous Riparian Woody Cover.	Riparian zone.	Maintain indigenous riparian woody cover below 10%.	An increase in riparian woody cover above 10%.		0% recorded.
	Non - woody Indigenous Cover (grasses, sedges and dicotyledonous forbs).	Marginal zone.	Maintain non - woody cover between 60 and 90%.	A decrease in non - woody cover below 50%.		40 - 60% recorded during VEGRAI assessment.
		Lower zone.	Maintain non - woody cover above 70%.	A decrease in non - woody cover below 60%.		60 - 80% recorded during VEGRAI assessment.
		Upper zone.	Maintain non - woody cover above 70%.	A decrease in non - woody cover below 80%.		80 - 100% recorded during VEGRAI assessment.
	Phragmites (reed) cover.	Riparian zone.	Maintain the absence of reeds.	A presence of reeds.		Only a small amount observed on the lower zone < 5%, but are not expected.

10.4.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data

Colour coding in the table below refers to:

EcoSpecs	TPC	Baseline	PES and REC

EC	Perennial Exotics (%)	Terrestrialization (%)	Riparian Woody (%)	Non-woody (%)	Reeds (%)
Marginal Zone					
A	0	0	0 - 5	70 - 80	0
A/B	1 - 5	0	5 - 10	60 - 70 ; 80 - 90	0
B	5 - 10	0	10 - 15	50 - 60; > 90	0
B/C	10 - 15	0	15 - 20	40 - 50	0
C	15 - 20	0	20 - 30	30 - 40	0
C/D	20 - 30	0	30 - 40	20 - 30	1 - 5
D	30 - 50	1 - 5	40 - 50	10 - 20	5 - 10
D/E	50 - 60	5 - 10	50 - 60	1 - 10	10 - 15
E	60 - 70	10 - 15	60 - 70	0	15 - 20
E/F	70 - 80	15 - 20	70 - 80		20 - 25
F	> 80	> 20	> 80		> 25
Lower Zone					
A	0	0	0 - 5	80 - 90	0
A/B	1 - 5	0	5 - 10	70 - 80 ; > 90	0
B	5 - 10	0	10 - 15	60 - 70	0
B/C	10 - 15	1 - 5	15 - 20	50 - 60	0
C	15 - 20	5 - 10	20 - 30	40 - 50	0
C/D	20 - 30	10 - 15	30 - 40	30 - 40	1 - 10
D	30 - 50	15 - 20	40 - 50	20 - 30	10 - 20
D/E	50 - 60	20 - 30	50 - 60	10 - 20	20 - 30
E	60 - 70	30 - 40	60 - 70	5 - 10	30 - 40

EC	Perennial Exotics (%)	Terrestrialization (%)	Riparian Woody (%)	Non-woody (%)	Reeds (%)
E/F	70 - 80	40 - 50	70 - 80	1 - 5	40 - 50
F	> 80	> 50	> 80		> 50
Floodplain					
A	0	0 - 5	0 - 5	80 - 90	0
A/B	1 - 5	5 - 10	5 - 10	70 - 80 ; > 90	0
B	5 - 10	10 - 15	10 - 15	50 - 70	0
B/C	10 - 15	15 - 20	15 - 20	30 - 50	0
C	15 - 20	20 - 30	20 - 25	20 - 30	0
C/D	20 - 30	30 - 40	25 - 30	1 - 20	0
D	30 - 50	40 - 50	30 - 40	0	1 - 5
D/E	50 - 60	50 - 60	40 - 50		5 - 10
E	60 - 70	60 - 70	50 - 60		10 - 15
E/F	70 - 80	70 - 80	60 - 70		15 - 20
F	> 80	> 80	> 70		> 20

10.5 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 10.5.1. The spatial FROC of EWR 7 is provided in Section 10.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

10.5.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES					REC
			EWR SITE			REACH		REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
3	Species richness.	All indigenous species.	One of three expected indigenous fish species to be sampled (as per EWR baseline survey).	No fish species during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity - depth categories and cover features (to be quantified by RHAM).	All indigenous species.	Baseline (PES) FRAI score of 86.7% (B) calculated for the reach. Any decreased FROC in reach of BAEN, BANO and BPAL (refer to FROC: Table 2[1]) OR FRAI scores decreasing below 82.02% (category B/C).	Same as PES
2	Relative abundance.	N/A	Sampled at 0.1 individuals per minute electrofishing.	Relative abundance of less than 0.05 individual per minute sampled at the site (during same season as baseline data) when habitat can be sampled efficiently.	N/A	N/A	N/A	
4	Alien fish species.	Any alien/introduced spp.	(MSAL) sampled at relative abundance of 0.018 indiv/min during baseline surveys	Presence of more than one (> 1) alien/introduced fish species at site during any survey or MSAL at relative abundance > 0.04 indiv/min electro fishing.	N/A	Any alien/introduced spp.	Presence of more than one (> 1) alien/introduced fish species in reach during any survey.	
1	FD and FS habitats, flow dependant spp (flow alteration), water column.	BAEN	BAEN only fish species sampled at a relative abundance of 0.1 indiv/min (electrofishing).	BAEN present less than 100% of time (electrofishing during similar season/conditions) **AND/OR** decrease in relative abundance of < 0.06 indiv/min.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows). Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows), Reduction in suitability of water column (i.e. increased sedimentation of pools). To be quantified with RHAM.	BAEN	Any decreased FROC in reach of BAEN (refer to FROC, column F: Table 2).	
1	Substrate.	BAEN	BAEN present only fish species sampled at a relative abundance of 0.1 indiv/min (electrofishing).	BAEN present less than 100% of time (electrofishing during similar season/conditions) **AND/OR** decrease in relative abundance of < 0.06 indiv/min.	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates. To be quantified with RHAM.	BAEN BPAL	Any decreased FROC in reach of BAEN and BPAL (refer to FROC, column F: Table 2).	
1	Water quality intolerance.	BAEN	BAEN present at a relative abundance of 0.1 indiv/min (electrofishing).	BAEN present less than 100% of time (electrofishing during similar season/conditions) **AND/OR** decrease in relative abundance of < 0.06 indiv/min.	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	BPAL BANO	Any decreased FROC in reach of BANO and BPAL (refer to FROC, column F: Table 2).	
1	SD habitats.	BAEN	BAEN present at a relative abundance of 0.1 indiv/min (electrofishing).	BAEN present less than 100% of time (electrofishing during similar season/conditions) **AND/OR** decrease in relative abundance of < 0.06 indiv/min.	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools). To be quantified with RHAM.	BANO BAEN	Any decreased FROC in reach of BANO and BAEN (refer to FROC, column F: Table 2).	

Rank	Metric	Indicator spp.	PES						REC
			EWR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
5	SS habitats, overhanging and instream vegetation.	No indicator species for SS habitats present at site.				BANO	BPAL	Any decreased FROC in reach of BANO and BPAL (refer to FROC, column F: Table 2).	
6	Undercut banks.	No indicator species of undercut banks expected/present at site or reach.							

1 Refer to electronic data (DWA, 2010a).

10.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (B)		REC (B[1])
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
BAEN	***Labeobarbus aeneus* (Burchell, 1822)**	**3**	**2**	**1**	**Same as PES**
BANO	*Barbus anoplus* (Weber, 1897)	3	3	2	
BPAL	*Barbus pallidus* (Smith, 1841)	3	3	2	
(species in bold sampled at EWR site during baseline surveys)					

1 The PES was a D EC due to the impact of alien species (MSAL). However due to the optimal habitat alien species were ignored and the PES was set at a B EC.

10.6 MACROINVERTEBRATES

10.6.1 Reference Conditions

Reference conditions are based on professional judgment and data collected by Dr Mark Chutter from his Sites 9 (this site) and 9A (Chutter, 1967: Table 11).

10.6.2 Baseline Description

Baseline biomonitoring data available for EWR 7 are limited to a single survey conducted on 9th April 2008. The MIRAI indicated a Category B (85.3%). The available instream aquatic biotopes were poor and limited to a small riffle upstream of a road bridge. As such, the site was not suitable for the application of SASS. The riffle was made up of mainly wood debris that had accumulated upstream of the bridge, plus small stones and gravels in current that provided reasonable habitat for flow - dependent species. The site provides the best available sampling instream biotopes, although it is unrepresentative of the type of stream, which is a meandering lowland system that is naturally devoid of fast - flowing water. Oxbow lakes were abundant in the area, and although the diversity of macroinvertebrates in each of these lakes was low, each lake supported a different biota, so the macroinvertebrate diversity of the combined lakes was high.

10.6.3 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration, were recorded at the site during baseline sampling, and were selected as monitoring indicators for EWR 7.

Family	Flow				Substrate					Water Quality		
	Standing (<0.1 m/s)	Slow (0.1 - 0.3 m/s)	Mod (0.3 - 0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Veg	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7 - 10)	Low (SASS 4 - 6)
Baetidae (>2 spp)	●	●	⬤	⬤	●	●	⬤	●	●		10	
Leptophlebiidae (Prongills)	●	⬤	●		●	●	⬤	●	⬤		9	
Elmidae (Riffle beetles)			●	⬤		⬤	●	●			8	
Lestidae	●	●						⬤			8	
Hydropsychidae (2 spp)			●	⬤	●	⬤	●					5
Dytiscidae (Diving beetles)	⬤	●						⬤				5
Veliidae	●	●							⬤			5
Heptageniidae (Flathead mayflies)		●	●	●		●	⬤	●		13		
Hydropsychidae (>2 spp)			●	⬤	●	⬤	●			12		
Perlidae (Stoneflies)			●	⬤		●	⬤			12		
Psephenidae (Water pennies)			●	⬤		⬤	●				10	
Athericidae		●	⬤			●	⬤	●			10	
Tricorythidae (Stout crawlers)			●	⬤	●	⬤	⬤	●			9	
Atyidae (Freshwater shrimps)		●						⬤			8	
Ancylidae	●	●	●	●	●	●	●	●				6
Caenidae (Squaregills)	●	⬤				●	⬤	●	●			6
Simuliidae (Blackflies)		●	⬤	⬤	⬤	⬤	⬤	⬤				5

● = Partial Preference ⬤ = Strong Preference

The Leptophlebiid mayfly *Adenophlebia auriculata* was recorded at this site during baseline sampling. This species is easy to identify and is highly sensitive to changes in water quality, and therefore provides a highly suitable candidate for monitoring. Two species of caddisfly were recorded at this site, including the characteristic *Hydropsyche longifurca.*

10.6.4 EcoSpecs and TPCs relating to the MIRAI data: PES and REC

EcoSpecs and TPCs for the PES and REC (B) at EWR 7 are provided below:

ECOSPECS: Biota	TPCS
MIRAI Score between 80% and 87%.	MIRAI Score < 82%.
Baetidae > 2 spp.	Baetidae < 2 spp.
Leptophlebiidae (*A. auriculata*).	Leptophlebiidae (*A. auriculata*) absent from two or more consecutive surveys.
Elmiidae present.	Elmiidae absent on two or more consecutive surveys.
Lestidae present.	Lestidae absent from two or more consecutive surveys.
Hydropsychidae > 2 spp present.	Hydropsychidae < 2 spp in two or more consecutive surveys.
Dytiscidae present.	Dytiscidae absent from two or more consecutive surveys.
Veliidae present.	Veliidae absent on two or more consecutive surveys.

11 EWR 8: BAVARIA (WILGE RIVER)

A summary of the EcoClassification results are provided below (DWA, 2009c).

11.1 ECOCLASSIFICATION SUMMARY OF EWR 8

EWR 8 Bavaria (Wilge River)

EIS: MODERATE
PES: C
Flow related impacts include alteration of hydrological regime due to interbasin transfers from Sterkfontein Dam, abstraction and agriculture. Non - flow related impacts include water quality problems, erosion and exotic species invasion.

REC: C.
Maintain the PES due to the **MODERATE** EIS rating.

AEC Up: B/C
Dry season base flow increase and no zero flows.
Ongoing improved management of the Sterkfontein Dam releases.
Reduced grazing, burning and removal of debris.
Removal of MSAL (although highly impractical, without this removal, the fish EC will not improve).

AEC Down: D
Further decrease of base flows (e.g. an additional dam).
Decrease in small moderate floods.
Associated water quality deterioration.

IHI				Driver Components	PES and REC Category	Trend	AEC ↑	AEC↓
INSTREAM	C/D	RIPARIAN	C	HYDROLOGY	D			
				WATER QUALITY	C	Stable	B/C	C/D
				GEOMORPHOLOGY	C	Positive	+C	C/D
				Response Components	PES Category	Trend	AEC ↑	AEC↓
				FISH	C	Stable	B	D
				MACRO INVERTEBRATES	C/D	Stable	C	D
				INSTREAM	C		B/C	D
				RIPARIAN VEGETATION	C	Stable	B/C	D
				ECOSTATUS	C		B/C	D

EcoSpecs and TPCs are provided for the different components in Section 11.2 to 11.7.

11.2 GEOMORPHOLOGY

EcoSpecs and TPCs based on the GAI are provided in Section 10.2.1.

11.2.1 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Descriptor	EcoSpec	TPC
Bed material composition	Sampling of the dry season bed material at the EWR site (using a sample size of not less than 500 points) should be undertaken at the prescribed intervals (every 5 years) to assess impacts of flow on the bed sediment and therefore as an indication of the change of available habitat for instream biota. Fining of the bed (i.e. decreases in the size of the 16th, 50th and 84th percentiles of the sediment size distribution as indicated to the left) would indicate insufficient flows being delivered to the site to maintain the geomorphological condition.	
	D_{16} = 1 mm	D_{16} sediment size must be greater than 0.5 mm
	D_{50} = 40 mm	D_{50} sediment size must be greater than 20 mm
	D_{84} = 260 mm	D_{84} sediment size must be greater than 150 mm
Channel morphology	The bedrock nature of the site makes it resistant to morphological adjustment. . Therefore ***monitoring of the cross - section at this site is not required.***	
	The alluvial banks upstream of the site cut extensively on both sides, and large volumes of exotic woody debris at the site suggest that bank erosion is accelerating and eroding the trees from the banks throughout the reach. Aerial photographs should be used to monitor the extent of cut banks throughout the reach. To maintain the PES, the extent should not increase.	
		Any increase in the extent and/or severity of cut banks

11.3 PHYSICO - CHEMICAL VARIABLES

TPCs and EcoSpecs are provided in Section 11.3.1 – 11.3.2.

11.3.1 EcoSpecs relating to physico - chemical data: PES and REC

River: Vaal		EWR 8
Water quality metrics		**EcoSpecs: PES and REC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be < 16 mg/L.
	Na_2SO_4	The 95th percentile of the data must be < 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be < 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be < 21 mg/L.
	NaCl	The 95th percentile of the data must be < 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be < 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be < 55 mS/m.
	pH	The 5th and 95th percentiles of the data must be between 5.9 – 6.5and 8.0 – 8.8.
	Temperature	Initiate baseline monitoring for this variable.
	Dissolved oxygen	Must be between 7 and 8 mg/L.
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
Nutrients	TIN	The 50th percentile of the data must be < 0.7 mg/L.
	PO_4 - P	The 50th percentile of the data must be < 0.025 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be < 15 µg/L.
	Chl - a periphyton	The 50th percentile of the data must be < 12 mg/m^2.
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

11.3.2 TPCs relating to physico - chemical data

River: Vaal		EWR 8
Water quality metrics		**TPC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be < 16 mg/L.
	Na_2SO_4	The 95th percentile of the data must be < 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be < 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be < 21 mg/L.
	NaCl	The 95th percentile of the data must be < 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be 280 – 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be < 55 mS/m.
	pH	The 5th and 95th percentiles of the data must be between 5.9 – 6.5and 8.0 – 8.8.
	Temperature	Initiate baseline monitoring for this variable.
	Dissolved oxygen	Must be between 7 and 8 mg/L.
Nutrients	TIN	The 50th percentile of the data must be between 0.25 and 0.7 mg/L.
	PO_4 - P	The 50th percentile of the data must be between 0.015 and 0.025 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be between 10 and 15 µg/L.
	Chl - a periphyton	The 50th percentile of the data must be 1.7 to 12 mg/m^2.
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

11.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the VEGRAI data are provided Section 11.4.1 to 11.4.2.

11.4.1 EcoSpecs and TPCs description relating to VEGRAI monitoring data: PES and REC

PES and REC	Assessed Component	Zone Assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)
C	Exotic Invasion (perennial exotics).	Marginal zone.	Maintain perennial exotic species cover below 20%.	An increase in perennial exotic species above 5%.	Same as PES.
		Lower zone.	Maintain perennial exotic species cover below 20%.	An increase in perennial exotic species above 20%.	
		Upper zone.	Maintain perennial exotic species cover below 20%.	An increase in perennial exotic species above 5%.	
	Terrestrial woody species cover.	Marginal zone.	Maintain the absence of terrestrial woody species.	The presence of terrestrial woody species.	
		Lower zone.	Maintain cover of terrestrial woody species below 10%.	An increase in woody terrestrial species covers above 5%.	
		Upper zone.	Maintain cover of terrestrial woody species below 30%.	An increase in woody terrestrial species covers above 30%.	
	Indigenous Riparian Woody Cover.	Marginal zone.	Maintain indigenous riparian woody cover below 50%, but retain presence i.e. not 0%.	An absence of riparian woody cover OR an increase above 50%.	
		Lower zone.	Maintain indigenous riparian woody cover below 30%.	An increase in riparian woody cover above 10%.	
		Upper zone.	Maintain indigenous riparian woody cover below 25%.	An increase in riparian woody cover above 10%.	
	Non - woody Indigenous Cover (grasses, sedges and dicotyledonous forbs).	Marginal zone.	Maintain non - woody cover above 30%, with sedges predominating.	A decrease in non - woody cover below 30%.	
		Lower zone.	Maintain non - woody cover above 40%.	A decrease in non - woody cover below 60%.	
		Upper zone.	Maintain non - woody cover above 20%, with grasses predominating.	A decrease in non - woody cover below 70%.	
	Phragmites (reed) cover.	Riparian zone.	Maintain the absence of reeds.	A presence of reeds.	

11.4.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data

Colour coding in the table below refers to:

EcoSpecs	TPC	Baseline	PES and REC

EC	Perennial Exotics (%)	Terrestrialization (%)	Riparian Woody (%)	Non-woody (%)	Reeds (%)
Marginal Zone					
A	0	0	5 - 10	70 - 80	0
A/B	1 - 5	0	10 - 20	60 - 70; 80 - 90	0
B	5 - 10	0	1 - 5 ; 20 - 30	50 - 60; > 90	0
B/C	10 - 15	0	30 - 40	40 - 50	0
C	15 - 20	0	40 - 50	30 - 40	0
C/D	20 - 30	0	0 ; 50 - 60	20 - 30	1 - 5
D	30 - 50	1 - 5	60 - 70	10 - 20	5 - 10
D/E	50 - 60	5 - 10	70 - 80	1 - 10	10 - 15
E	60 - 70	10 - 15	80 - 90	0	15 - 20
E/F	70 - 80	15 - 20	> 90		20 - 25
F	> 80	> 20			> 25

EC	Perennial Exotics (%)	Terrestrialization (%)	Riparian Woody (%)	Non-woody (%)	Reeds (%)
Lower Zone					
A	0	0	0 - 5	80 - 90	0
A/B	1 - 5	0	5 - 10	70 - 80; > 90	0
B	5 - 10	0	10 - 15	60 - 70	0
B/C	10 - 15	1 - 5	15 - 20	50 - 60	0
C	15 - 20	5 - 10	20 - 30	40 - 50	0
C/D	20 - 30	10 - 15	30 - 40	30 - 40	1 - 10
D	30 - 50	15 - 20	40 - 50	20 - 30	10 - 20
D/E	50 - 60	20 - 30	50 - 60	10 - 20	20 - 30
E	60 - 70	30 - 40	60 - 70	5 - 10	30 - 40
E/F	70 - 80	40 - 50	70 - 80	1 - 5	40 - 50
F	> 80	> 50	> 80		> 50
Upper Zone					
A	0	0 - 5	0 - 5	80 - 90	0
A/B	1 - 5	5 - 10	5 - 10	70 - 80; > 90	0
B	5 - 10	10 - 15	10 - 15	50 - 70	0
B/C	10 - 15	15 - 20	15 - 20	30 - 50	0
C	15 - 20	20 - 30	20 - 25	20 - 30	0
C/D	20 - 30	30 - 40	25 - 30	1 - 20	0
D	30 - 50	40 - 50	30 - 40	0	1 - 5
D/E	50 - 60	50 - 60	40 - 50		5 - 10
E	60 - 70	60 - 70	50 - 60		10 - 15
E/F	70 - 80	70 - 80	60 - 70		15 - 20
F	> 80	> 80	> 70		> 20

11.5 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 11.5.1. The spatial FROC of EWR 8 is provided in Section 11.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

11.5.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES/REC						↑AEC
			EWR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
7	Species richness.	All indigenous species.	Six of an expected eight indigenous fish species to be sampled (as per EWR baseline survey)	Less than three species sampled during any survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity - depth categories and cover features (to be quantified by RHAM if applicable).	All indigenous species.		Baseline (PES) FRAI score of 76.1% (high C) calculated for the reach. Any decreased FROC in reach of especially ASCL, BAEN and LCAP (refer to FROC: Table 2[1]) OR FRAI scores decreasing below 68% (low category C).	An improvement from PES FROC in the reach for especially BANO and BPAU should be indicative of reaching/maintaining the improved AEC (refer to FROC sheet for more detail).
6	Relative abundance.	All indigenous species.	Fishsampled at > 0.4 individuals per minute (electrofishing).	Relative abundance of less than 0.3 individual per minute sampled at the site (during same seasons as baseline data) when habitat can be sampled efficiently using electrofishing.	N/A	N/A		N/A	
10	Alien fish species.	Any alien/introduced spp.	Two alien fish species (MSAL and CCAR) present. CCAR present 100% at a relative abundance of < 0.08 ind/min and MSAL 50% of time at < 0.009 indiv/min.	Increase in the number of alien species (> 2 species during any survey) **OR** increased relative abundance of CCAR > 0.1 indiv/min.	N/A	Any alien/ introduced spp.		Increase in the number of alien species (> 2 species in reach) **OR** presence of any alien species other than CCAR, and MSAL.	
1	FD habitats, flow dependant spp (flow alteration), water column.	BAEN, LCAP	BAEN and LCAP sampled 100% of time. BAEN present at relative abundance of > 0.09 indiv/min. and LCAP at relative abundance of > 0.19 indiv/min.	BAEN **OR** LCAP present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.05 indiv/min for BAEN and < 0.13 indiv/min for LCAP.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows), Reduction in suitability of water column (i.e. increased sedimentation of pools). To be quantified with RHAM.	BAEN	LCAP	Any decreased FROC in reach of BAEN and LCAP (refer to FROC, column F: Table 2).	
2	FS habitats.	BAEN, ASCL	BAEN and ASCL sampled 100% of time. BAEN present at relative abundance of > 0.09 indiv/min. and ASCL at relative abundance of > 0.02 indiv/min.	BAEN **OR** ASCL present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.05 indiv/min for BAEN and < 0.01 indiv/min for ASCL	Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows). To be quantified with RHAM.	BAEN	ASCL	Any decreased FROC in reach of BAEN and ASCL (refer to FROC, column F: Table 2).	
3	Substrate.	ASCL, LCAP	ASCL and LCAP sampled 100% of time. ASCL present at relative abundance of > 0.02 indiv/min. and LCAP at relative abundance of > 0.19 indiv/min.	ASCL **OR** LCAP present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.01 indiv/min for ASCL and < 0.13 indiv/min for LCAP.	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates. To be quantified with RHAM.	ASCL	LCAP	Any decreased FROC in reach of ASCL and LCAP (refer to FROC, column F: Table 2).	
4	Water quality intolerance.	LCAP (BPAL and BANO abundance too low)	LCAP sampled 100% of time at relative abundance of > 0.19 indiv/min.	LCAP present less than 100% of time (not sampled during any survey) **OR** decrease in relative abundance of < 0.13 indiv/min.	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	BPAL	LCAP	Any decreased FROC in reach of BPAL and LCAP (refer to FROC, column F: Table 2).	

Rank	Metric	Indicator spp.	PES/REC					↑AEC
			EWR SITE			REACH		REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
4	SD habitats.	(LUMB) LCAP	LCAP sampled 100% of time at relative abundance of > 0.19 indiv/min. LUMB only sampled 50% of time and through use of gill nets.	LCAP present less than 100% of time (not sampled during any survey) **OR** decrease in relative abundance of < 0.13 indiv/min.	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools). To be quantified with RHAM.	LUMB CGAR	Any decreased FROC in reach of LUMB and CGAR (refer to FROC, column F: Table 2).	
8	SS habitats.	BANO, BPAL	BANO and BPAL present in very low abundance during 50% of survey. BANO at relative abundance of 0.01 indiv/min and BPAL at 0.008 indiv/min.	Absence of BANO AND BPAL during 2 consecutive surveys.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats). To be quantified with RHAM.	BANO CGAR	Any decreased FROC in reach of BANO and CGAR (refer to FROC, column F: Table 2).	
9	Overhanging and instream vegetation.	BANO (BPAL)	BANO and BPAL present in very low abundance during 50% of surveys. BANO at relative abundance of 0.01 indiv/min and BPAL at 0.008 indiv/min.	Absence of BANO AND BPAL during 2 consecutive surveys.	Significant change in overhanging and instream vegetation habitats (to be quantified with RHAM).	BANO BPAU	Any decreased FROC in reach of BANO and BPAU (refer to FROC, column F: Table 2).	
5	Undercut banks.	ASCL	ASCL was sampled 100% of time at relative abundance of > 0.02 indiv/min.	ASCL present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.01 indiv/min.	Significant change in undercut bank habitats (to be quantified with RHAM).	ASCL	Any decreased FROC in reach of ASCL (refer to FROC, column F: Table 2).	

1 Refer to electronic data (DWA, 2010a).

11.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (C)		AEC up (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
BAEN	***Labeobarbus aeneus* (Burchell, 1822)**	**3**	**3**	**2**	**3**
BANO	***Barbus anoplus* (Weber, 1897)**	**3**	**2**	**1**	**2.5**
BPAL	***Barbus pallidus* (Smith, 1841)**	**2**	**1**	**0**	**1**
BPAU	*Barbus paludinosus* (Peters, 1852)	2	1	0	**1.5**
ASCL	***Austroglanis sclateri* (Boulenger, 1901)**	**3**	**3**	**2**	**3**
CGAR	*Clarias gariepinus* (Burchell, 1822)	3	3	2	3
LCAP	***Labeo capensis* (Smith, 1841)**	**3**	**3**	**2**	**3**
LUMB	***Labeo umbratus* (Smith, 1841)**	**3**	**3**	**2**	**3**
(species in bold sampled at EWR site during baseline surveys)					

11.6 MACROINVERTEBRATES

11.6.1 Reference Conditions

Reference conditions are based on professional judgment and data collected by Dr Mark Chutter from his Site 12 (this site) (Chutter, 1967: Table 11). The reference SASS5 Score is 185 and the ASPT is 6.0.

11.6.2 Baseline Description

Baseline biomonitoring data available for EWR 8 are summarised as follows:

Date	SASS5 Score	ASPT	No. of Taxa	Category (Dallas 2007)	MIRAI (%)	MIRAI Category
10-04-08	115	5.0	23	D	60.8%	C/D
19-09-07	118	5.4	22	C/D		

11.6.3 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration, were recorded at the site during baseline sampling, and were selected as monitoring indicators for EWR 8.

Family	Flow				Substrate					Water Quality		
	Standing (<0.1 m/s)	Slow (0.1 - 0.3 m/s)	Mod (0.3 - 0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Vegetation	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7 - 10)	Low (SASS 4 - 6)
Hydropsychidae (>2 spp)			●	⬤	●	⬤	●			12		
Baetidae (>2 spp)	●	●	⬤	⬤	●	●	⬤	●	●		10	
Leptophlebiidae (Prongills)	●	⬤	●		●	●	⬤	●	⬤		9	
Ancylidae	●	●	●	●	●	●	●	●				6
Simuliidae (Blackflies)		●	⬤	⬤	⬤	⬤	⬤	⬤				5
Heptageniidae (Flathead mayflies)		●	●	●		●	⬤	●		13		
Perlidae (Stoneflies)			●	⬤		●	⬤			12		
Psephenidae (Water pennies)			●	⬤		⬤	●				10	
Athericidae		●	⬤			●	⬤	●			10	
Tricorythidae (Stout crawlers)			●	⬤	●	⬤	⬤	●			9	
Atyidae (Freshwater shrimps)		●						⬤			8	
Elmidae (Riffle beetles)			●	⬤		⬤	●	●			8	
Lestidae	●	●						⬤			8	
Caenidae (Squaregills)	●	⬤				●	⬤	●	●			6
Hydropsychidae (2 spp)			●	⬤	●	⬤	●					5
Dytiscidae (Diving beetles)	⬤	●						⬤				5

● = Partial Preference ⬤ = Strong Preference

Caddisflies recorded at the site during baseline sampling included *Cheumatopsyche thomasseti, C. afra, Aethaloptera maxima* and *Amphipysche scottae.* The site also supported freshwater sponge and Sisyridae, which feed exclusively on sponges. Three families of bivalve were recorded at the site (Sphaeridae, Unionidae and Corbiculidae), although one of these was found as empty shells only (Unionidae). The pest blackfly *Simulium chutteri*, was abundant in April 2008.

11.6.4 EcoSpecs and TPCs relating to the MIRAI data: PES and REC

EcoSpecs and TPCs for the PES and REC (C/D) at EWR 8 are provided below:

ECOSPECS: Biota	TPCS
SASS5 Score between 102 and 132.	SASS5 Score < 109.
ASPT between 4.9 and 5.5.	ASPT < 5.1.
MIRAI Score between 56% and 63%.	MIRAI Score < 58%.
Hydropsychidae > 2 spp present.	Hydropsychidae < 2 spp in two or more consecutive surveys.
Baetidae > 2 spp.	Baetidae < 2 spp.
Leptophlebiidae present.	Leptophlebiidae absent from two or more consecutive surveys.
Ancylidae present.	Ancylidae absent from two or more consecutive surveys.
Simuliidae present.	Simuliidae absent on two or more consecutive surveys.

12 EWR 9: SUIKERBOS US (SUIKERBOSRAND RIVER)

A summary of the EcoClassification results are provided below (DWA, 2009c).

12.1 ECOCLASSIFICATION SUMMARY OF EWR 9

EWR 9 Suikerbos US (Suikerbosrand River)

EIS: HIGH
There are endangered species at this site, which includes *Labeobarbus kimberleyensis* and the Soweto Highveld grassland vegetation type (conservation status: endangered).

PES: C
Combination of flow and non - flow related impacts. Flow related impacts include altered flow regime due to Balfour and Harhoff Dams and non - flow related impacts include deteriorated water quality due to WWTW and agriculture, erosion and alien species (fish and vegetation).

REC: B/C
Improvement of the PES due to **HIGH** EIS rating.
An improvement is based on increased base flows (released from upstream dams) as well as erosion control measures in the tributaries to address erosion and increased sediment loads in the reach and alien woody vegetation control.

AEC Down: D
This scenario was not developed as the macroinvertebrates and fish are already in a D EC. A D AEC would involve the maintenance of the current ECs of fish and macroinvertebrates and a deterioration of the riparian vegetation EC. Any flow related changes will however cause deterioration in the riparian vegetation EC and would result in the instream and biota ECs to drop to an E.

IHI			Driver Components	PES Category	Trend	REC
INSTREAM	D	RIPARIAN B	HYDROLOGY	E		
			WATER QUALITY	C/D	Negative D	C
			GEOMORPHOLOGY	B/C	Negative C	B
			Response Components	**PES Category**	**Trend**	**REC**
			FISH	D	Stable	C
			MACRO INVERTEBRATES	D	Stable	C
			INSTREAM	D		C
			RIPARIAN VEGETATION	B/C	Negative C/D	B
			ECOSTATUS	C		B/C

EcoSpecs and TPCs are provided for the different components in Section 12.2 to 12.7.

12.2 GEOMORPHOLOGY

EcoSpecs and TPCs based on the GAI are provided in Section 12.2.1.

12.2.1 EcoSpecs and TPCs relating to GAI monitoring data: PES

Descriptor	EcoSpec	TPC
Bed material composition	Sampling of the dry season bed material at the EWR site (using a sample size of not less than 500 points) should be undertaken at the prescribed intervals (every 5 years) to assess impacts of flow on the bed sediment and therefore as an indication of the change of available habitat for instream biota. Fining of the bed (i.e. decreases in the size of the 16th, 50th and 84th percentiles of the sediment size distribution as indicated to the left) would indicate (1) insufficient flows being delivered to the site to maintain the geomorphological condition, and/or (2) excessive catchment erosion.	
	D_{16} = 20 mm	D_{16} sediment size must be greater than 10 mm
	D_{50} = 170 mm	D_{50} sediment size must be greater than 120 mm
	D_{84} = 320 mm	D_{84} sediment size must be greater than 250 mm
Channel morphology	The banks and cross - section shape is largely natural at present, but erosion in the catchment has increased the fines load of the river, so possibly the pools are infilling and channels reducing in width due to sedimentation. Aggradation (increased bed level) in conjunction with fining of the bed material would indicate the TPC exceedence. Cross - section resurveying at 5 year intervals should be employed to assess this.	
		Any increase in the bed (aggradation) of the pools at cross section scale.

12.3 PHYSICO - CHEMICAL VARIABLES

TPCs and EcoSpecs are provided in Section 12.3.1 – 12.3.2.

12.3.1 EcoSpecs relating to physico - chemical data: PES

River: Vaal		EWR 9
Water quality metrics		**EcoSpecs: PES**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be < 16 mg/L.
	Na_2SO_4	The 95th percentile of the data must be < 23 mg/L.
	$MgCl_2$	The 95th percentile of the data must be < 33 mg/L.
	$CaCl_2$	The 95th percentile of the data must be < 30 mg/L.
	NaCl	The 95th percentile of the data must be < 57 mg/L.
	$CaSO_4$	The 95th percentile of the data must be < 191 mg/L.
Physical variables	EC	The 95th percentile of the data must be < 351 mg/L.
	pH	The 95th percentile of the data must be < 85 mS/m.
	Temperature	The 5th and 95th percentiles of the data must be between 6.5 – 8.0 and 8.0 – 8.8.
	Dissolved oxygen	Must be between 7 and 8 mg/L.
	Turbidity	Initiate baseline monitoring for this variable.
Nutrients	TIN	The 50th percentile of the data must be < 0.7 mg/L.
	PO_4 - P	The 50th percentile of the data must be < 0.125 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be < 15 µg/L.
	Chl - a periphyton	The 50th percentile of the data must be 1.7 to 12 mg/m^2.
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

12.3.2 TPCs relating to physico - chemical data

River: Vaal		EWR 9
Water quality metrics		**TPC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be < 23 mg/L.
	Na_2SO_4	The 95th percentile of the data must be < 33 mg/L.
	$MgCl_2$	The 95th percentile of the data must be < 30 mg/L.
	$CaCl_2$	The 95th percentile of the data must be < 57 mg/L.
	NaCl	The 95th percentile of the data must be < 191 mg/L.
	$CaSO_4$	The 95th percentile of the data must be 280 – 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be < 85 mS/m.
	pH	The 5th and 95th percentiles of the data must be between 6.5 – 8.0 and 8.0 – 8.8.
	Temperature	Initiate baseline monitoring for this variable.
	Dissolved oxygen	Must be between 7 and 8 mg/L.
Nutrients	TIN	The 50th percentile of the data must be between 0.25 and 0.7 mg/L.
	PO_4 - P	The 50th percentile of the data must be between 0.025 and 0.125 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be between 10 and 15 µg/L.
	Chl - a periphyton	The 50th percentile of the data must be 1.7 to 12 mg/m^2.
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

12.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the VEGRAI data are provided Section 12.4.1 to 12.4.2.

12.4.1 EcoSpecs and TPCs description relating to VEGRAI monitoring data: PES and REC

PES	REC	Assessed Component	Zone Assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Baseline Note
B/C	B	Exotic Invasion (perennial exotics).	Marginal zone.	Maintain perennial exotic species cover below 15%.	The presence of perennial exotic species.	Maintain perennial exotic species cover below 10%.	< 10%, non - woody weeds.
			Lower zone.	Maintain perennial exotic species cover below 15%.	An increase in perennial exotic species above 15%.	Maintain perennial exotic species cover below 10%.	10 - 20%, mostly non - woody weeds, but with *Salix babylonica.*
			Upper zone.	Maintain perennial exotic species cover below 15%.	An increase in perennial exotic species above 15%.	Maintain perennial exotic species cover below 10%.	Woody and non - woody mix about 40% exotics.
		Terrestrial woody species cover.	Marginal zone.	Maintain the absence of terrestrial woody species.	The presence of terrestrial woody species.	Same as PES.	No woody terrestrial species were recorded.
			Lower zone.	Maintain cover of terrestrial woody species below 5%.	An increase in woody terrestrial species covers above 5%.	Maintain the absence of terrestrial woody species.	10 - 20% terrestrial woody species cover
			Upper zone.	Maintain cover of terrestrial woody species below 20%.	An increase in woody terrestrial species covers above 20%.	Maintain cover of terrestrial woody species below 15%.	20 - 30% recorded.
		Indigenous Riparian Woody Cover.	Marginal zone.	Maintain indigenous riparian woody cover below 40%, but retain presence i.e. not 0%.	An absence of riparian woody cover OR an increase above 40%.	Maintain indigenous riparian woody cover below 30%, but retain presence i.e. not 0%.	40 - 60%, *Gomphostigma virgatum* and *Salix mucronata.*
			Lower zone.	Maintain indigenous riparian woody cover below 20%.	An increase in riparian woody cover above 20%.	Maintain indigenous riparian woody cover below 15%.	30 - 50%, *Gomphostigma virgatum* and *Salix mucronata.*
			Upper zone.	Maintain indigenous riparian woody cover below 20%.	An increase in riparian woody cover above 20%.	Maintain indigenous riparian woody cover below 15%.	< 10%.
		Non - woody Indigenous Cover (grasses, sedges and dicotyledonous forbs).	Marginal zone.	Maintain non - woody cover above 40%.	A decrease in non - woody cover below 40%.	Maintain non - woody cover above 50%.	20 - 40% recorded during VEGRAI assessment.
			Lower zone.	Maintain non - woody cover above 50%.	A decrease in non - woody cover below 50%.	Maintain non - woody cover above 60%.	20 - 40% recorded during VEGRAI assessment.
			Upper zone.	Maintain non - woody cover above 30%.	A decrease in non - woody cover below 30%.	Maintain non - woody cover above 50%.	40 - 60% recorded during VEGRAI assessment.
		Phragmites (reed) cover.	Riparian zone.	Maintain the absence of reeds.	A presence of reeds.	Maintain the absence of reeds.	Reeds were not observed at the site, and are not expected.

12.4.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data: PES

Colour coding in the table below refers to:

EcoSpecs	TPC	Baseline	PES	REC

EC	Perennial Exotics (%)	Terrestrialization (%)	Riparian Woody (%)	Non-woody (%)	Reeds (%)
Marginal Zone					
A	0	0	5 - 10	70 - 80	0
A/B	1 - 5	0	10 - 20	60 - 70 ; 80 - 90	0
B	5 - 10	0	1 - 5; 20 - 30	50 - 60; > 90	0
B/C	10 - 15	0	30 - 40	40 - 50	0
C	15 - 20	0	40 - 50	30 - 40	0

EC	Perennial Exotics (%)	Terrestrialization (%)	Riparian Woody (%)	Non-woody (%)	Reeds (%)
C/D	20 - 30	0	0 ; 50 - 60	20 - 30	1 - 5
D	30 - 50	1 - 5	60 - 70	10 - 20	5 - 10
D/E	50 - 60	5 - 10	70 - 80	1 - 10	10 - 15
E	60 - 70	10 - 15	80 - 90	0	15 - 20
E/F	70 - 80	15 - 20	> 90		20 - 25
F	> 80	> 20			> 25
Lower Zone					
A	0	0	0 - 5	80 - 90	0
A/B	1 - 5	0	5 - 10	70 - 80 ; > 90	0
B	5 - 10	0	10 - 15	60 - 70	0
B/C	10 - 15	1 - 5	15 - 20	50 - 60	0
C	15 - 20	5 - 10	20 - 30	40 - 50	0
C/D	20 - 30	10 - 15	30 - 40	30 - 40	1 - 10
D	30 - 50	15 - 20	40 - 50	20 - 30	10 - 20
D/E	50 - 60	20 - 30	50 - 60	10 - 20	20 - 30
E	60 - 70	30 - 40	60 - 70	5 - 10	30 - 40
E/F	70 - 80	40 - 50	70 - 80	1 - 5	40 - 50
F	> 80	> 50	> 80		> 50
Upper Zone					
A	0	0 - 5	0 - 5	80 - 90	0
A/B	1 - 5	5 - 10	5 - 10	70 - 80 ; > 90	0
B	5 - 10	10 - 15	10 - 15	50 - 70	0
B/C	10 - 15	15 - 20	15 - 20	30 - 50	0
C	15 - 20	20 - 30	20 - 25	20 - 30	0
C/D	20 - 30	30 - 40	25 - 30	1 - 20	0
D	30 - 50	40 - 50	30 - 40	0	1 - 5
D/E	50 - 60	50 - 60	40 - 50		5 - 10
E	60 - 70	60 - 70	50 - 60		10 - 15
E/F	70 - 80	70 - 80	60 - 70		15 - 20
F	> 80	> 80	> 70		> 20

12.5 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 12.5.1. The spatial FROC of EWR 9 is provided in Section 12.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

12.5.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES						REC
			EWR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
7	Species richness.	All indigenous species.	Four of an expected ten indigenous fish species to be sampled (as per EWR baseline survey).	Less than one fish species sampled during any survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity - depth categories and cover features (to be quantified by RHAM if applicable).	All indigenous species.		Baseline (PES) FRAI score of 53.3% (D) calculated for the reach. Any decreased FROC in reach of especially BAEN and LCAP (refer to FROC: Table 2[1]) OR FRAI scores decreasing below 45% (low category D).	An improvement from PES FROC in the reach for especially ASCL, BANO, BPAL and BKIM should be indicative of reaching/maintaining the improved REC (refer to FROC sheet for more detail).
6	Relative abundance.	All indigenous species.	Fish sampled at > 0.07 individuals per minute (electrofishing).	Relative abundance of less than 0.04 individual per minute sampled at the site (during same seasons as baseline data) when habitat can be sampled efficiently using electrofishing.	N/A	N/A		N/A	
8	Alien fish species.	Any alien/introduced spp.	One alien fish species (MSAL) present sampled 50% of time at 0.02 indiv/min.	Increase in the number of alien species (> 1 species during any survey) **OR** increased relative abundance of MSAL > 0.04 indiv/min.	N/A	Any alien/introduced spp.		Two alien fish species (MSAL and CCAR) known to be present in reach. Increase in the number of alien species (> 2 species in reach) **OR** presence of any alien species other than CCAR, and MSAL.	
1	FD habitats, flow dependant spp (flow alteration), water quality intolerance, water column.	BAEN, LCAP	BAEN and LCAP sampled 50% of time. BAEN present at relative abundance of 0.75 indiv/min. and LCAP at relative abundance of 0.47 indiv/min.	BAEN **OR** LCAP present less than 50% of time (not sampled during two consecutive surveys).	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates, Reduction in suitability of water column (i.e. increased sedimentation of pools) [to be quantified with RHAM].Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	BAEN	LCAP	Any decreased FROC in reach of BAEN and LCAP (refer to FROC, column F: Table 2).	
2	FS habitats.	BAEN	BAEN sampled 50% of time during baseline EWR surveys. BAEN present at relative abundance of 0.75 indiv/min.	BAEN present less than 50% of time (not sampled during two consecutive surveys).	Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows), To be quantified with RHAM.	BAEN	ASCL	Any decreased FROC in reach of BAEN and ASCL (refer to FROC, column F: Table 2).	
1	Substrate.	LCAP, BAEN	BAEN and LCAP sampled 50% of time. BAEN present at relative abundance of 0.75 indiv/min. and LCAP at relative abundance of	BAEN **OR** LCAP present less than 50% of time (not sampled during two consecutive surveys).	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates. To be quantified with RHAM.	ASCL	LCAP	Any decreased FROC in reach of ASCL and LCAP (refer to FROC, column F: Table 2).	

Rank	Metric	Indicator spp.	PES						REC
			EWR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
			0.47 indiv/min.						
3	SD habitats.	CGAR, LCAP	CGAR and LCAP sampled 50% of time. CGAR present at relative abundance of 0.025 indiv/min. and LCAP at relative abundance of 0.47 indiv/min.	CGAR **OR** LCAP present less than 50% of time (not sampled during two consecutive surveys).	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools). To be quantified with RHAM.	CGAR	LCAP	Any decreased FROC in reach of CGAR and LCAP (refer to FROC, column F: Table 2).	
4	SS habitats.	TSPA, CGAR	TSPA sampled 100% of time at relative abundance > 0.02 indiv/min, while CGAR sampled 50% of time at relative abundance of 0.025 indiv/min.	CGAR present less than 50% of time (not sampled during two consecutive surveys) AND/OR TSPA not present 100% of time OR present at relative abundance < 0.01 indiv/min.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats). To be quantified with RHAM.	BANO	PPHI	Any decreased FROC in reach of BANO and PPHI (refer to FROC, column F: Table 2).	
5	Overhanging and instream vegetation.	TSPA	TSPA sampled 100% of time at relative abundance > 0.02 indiv/min.	TSPA not present 100% of time **AND/OR** present at relative abundance < 0.01 indiv/min.	Significant change in overhanging and instream vegetation habitats (to be quantified with RHAM).	PPHI	TSPA	Any decreased FROC in reach of PPHI and TSPA (refer to FROC, column F: Table 2).	
9	Undercut banks.	No indicator species of undercut banks expected/present at site.			Significant change in undercut bank habitats (to be quantified with RHAM).	ASCL	PPHI	Any decreased FROC in reach of ASCL and PPHI (refer to FROC, column F: Table 2).	

1 Refer to electronic data (DWA, 2010a).

12.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (D)		REC (C)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
ASCL	*Austroglanis sclateri* (Boulenger, 1901)	4	1	0	2
BAEN	***Labeobarbus aeneus* (Burchell, 1822)**	**4**	**3**	**2**	**3**
BANO	*Barbus anoplus* (Weber, 1897)	4	1	0	2
BPAL	*Barbus pallidus* (Smith, 1841)	3	1	0	2
BKIM	*Labeobarbus kimberleyensis* (Gilchrist and Thompson, 1913)	3	0		2
CGAR	***Clarias gariepinus* (Burchell, 1822)**	**4**	**4**	**3**	**4**
LCAP	***Labeo capensis* (Smith, 1841)**	**4**	**3**	**2**	**3**
LUMB	*Labeo umbratus* (Smith, 1841)	3	2	1	2
PPHI	*Pseudocrenilabrus philander* (Weber, 1897)	4	2	1	2
TSPA	***Tilapia sparrmanii* (Smith, 1840)**	**4**	**4**	**3**	**4**
(species in bold sampled at EWR site during baseline surveys)					

12.6 MACROINVERTEBRATES

12.6.1 Reference Conditions

Reference conditions are based on professional judgment and data collected by Dr Mark Chutter from his Sites 7, 15, 16 and 17 (Chutter, 1967: Table 11). The reference SASS5 Score is 182 and the ASPT is 6.1.

12.7 Baseline Description

Baseline biomonitoring data available for EWR 9 are summarised as follows:

Date	SASS5 Score	ASPT	No. of Taxa	Category (Dallas 2007)	MIRAI (%)	PES
10 - 04 - 08	119	6.0	20	C	50.4%	D
10 - 08 - 07	69	5.8	12	D		

12.7.1 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration, were recorded at the site during baseline sampling, and were selected as monitoring indicators for EWR 9.

Family	Flow				Substrate					Water Quality		
	Standing (<0.1 m/s)	Slow (0.1 - 0.3 m/s)	Mod (0.3 - 0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Vegetation	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7 - 10)	Low (SASS 4 - 6)
Heptageniidae (Flathead mayflies)		●	●	●		●	⬤	●		13		
Baetidae (>2 spp)	●	●	⬤	⬤	●	●	⬤	●	●		10	
Leptophlebiidae (Prongills)	●	⬤	●		●	●	⬤	●	⬤		9	
Atyidae (Freshwater shrimps)		●						⬤			8	
Elmidae (Riffle beetles)			●	⬤		⬤	●	●			8	
Hydropsychidae (2 spp)			●	⬤	●	⬤	●					5
Simuliidae (Blackflies)		●	⬤	⬤	⬤	⬤	⬤	⬤				5
Hydropsychidae (>2 spp)			●	⬤	●	⬤	●			12		
Perlidae (Stoneflies)			●	⬤		●	⬤			12		
Psephenidae (Water pennies)			●	⬤		⬤	●				10	
Athericidae		●	⬤			●	⬤	●			10	
Tricorythidae (Stout crawlers)			●	⬤	●	⬤	⬤	●			9	
Lestidae	●	●						⬤			8	
Ancylidae	●	●	●	●	●	●	●	●				6
Caenidae (Squaregills)	●	⬤				●	⬤	●	●			6
Dytiscidae (Diving beetles)	⬤	●						⬤				5

● = Partial Preference ⬤ = Strong Preference

The diversity of macroinvertebrate taxa at this site was low, and this limited the selection of suitable monitoring indicators. Flatheaded mayflies (Heptageniidae) were not recorded at this site in August 2007, but they were recorded in April 2008. Two species of caddisflies were recorded at the site in August 2007, and three species were recorded in April 2008 (*Cheumatopsyche thomasseti, C. afra* and *Macrostenum capense*). Freshwater shrimps (Atyidae) were present on both sampling occasions. Blackfly species recorded in April 2008 were *Simulium adersi*, *S. damnosum* and *S. nigritarse.*

12.7.2 EcoSpecs and TPCs relating to the MIRAI data: PES and REC

EcoSpecs and TPCs for the PES (D) at EWR 9 are provided below:

ECOSPECS: Biota	TPCS
SASS5 Score between 64 and 125.	SASS5 Score < 72.
ASPT between 5.3 and 6.0.	ASPT < 5.5.
MIRAI Score between 42% and 57%.	MIRAI Score < 45%.
Baetidae > 2 spp.	Baetidae < 2 spp.
Leptophlebiidae present.	Leptophlebiidae absent from two or more consecutive surveys.
Atyidae present.	Atyidae absent on two or more consecutive surveys.
Elmiidae present.	Elmiidae absent on two or more consecutive surveys.
Hydropsychidae > 1 spp.	Hydropsychidae absent.

ECOSPECS: Biota	TPCS
Simuliidae present.	Simuliidae absent on two or more consecutive surveys.

EcoSpecs and TPCs for the REC (C) at EWR 9 are provided below:

ECOSPECS: Biota	TPCS
SASS5 Score between 125 and 159.	SASS5 Score < 130.
ASPT between 5.6 and 6.3.	ASPT < 5.8.
MIRAI Score between 62% and 77%.	MIRAI Score < 66%.
To ensure that no group consistently dominates the fauna, defined as C abundance (> 100) over two consecutive surveys.	Any taxon abundance 'D' (> 1000) in two consecutive surveys.
Heptageniidae present.	Heptageniidae absent on two or more consecutive surveys.
Baetidae > 2 spp.	Baetidae < 2 spp.
Leptophlebiidae present.	Leptophlebiidae absent from two or more consecutive surveys.
Atyidae present.	Atyidae absent on two or more consecutive surveys.
Elmiidae present.	Elmiidae absent on two or more consecutive surveys.
Hydropsychidae > 1 spp.	Hydropsychidae absent.
Simuliidae present.	Simuliidae absent on two or more consecutive surveys.

13 EWR 10: SUIKER DS (SUIKERBOSRAND RIVER)

A summary of the EcoClassification is provided below (DWA, 2009c).

13.1 ECOCLASSIFICATION SUMMARY OF EWR 10

The aims at EWR 10 were to maintain the PES as the REC. Two EWR scenarios were investigated, i.e. an improved (from PES) AEC and an AEC lower than the PES.

EWR 10 Suikerbos DS (Suikerbosrand River)

EIS: MODERATE
PES: C/D
Combination of flow and non - flow related impacts. Flow related impacts include elevated base flow and increased floods due to mining, SAPPI, urban runoff and Blesbokspruit input. Non - flow related impacts include deteriorated water quality due to industries, agriculture and urban activities; erosion, and exotic alien invasion (fish and vegetation).

REC: C/D
Maintain the PES due to the **MODERATE** EIS rating.

AEC up: C
Improved water quality management in the Blesbokspruit catchment. The biotic condition of the biota will improve under this scenario although no improvement will be evident in the riparian vegetation component. The riparian vegetation EC is associated with increased flows rather than water quality. **NOTE:** The recommendations at EWR 9 are to improve the low flows in the dry season. This could increase flows to the level that is problematic at EWR 10. This will have to be treated as a scenario in a systems context and evaluated.

AEC down: D
The scenario is increased base flows.

Driver Components	PES and REC Category	Trend	AEC ↑	AEC↓
HYDROLOGY	D			
WATER QUALITY	D/E	Negative	D	D/E
GEOMORPHOLOGY	C	Negative C	C	-C
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	C/D	Stable	C	D
MACRO INVERTEBRATES	C/D	Stable	C	D
INSTREAM	C/D		C	D
RIPARIAN VEGETATION	C	Negative D	C	D
ECOSTATUS	C/D		C	D

EcoSpecs and TPCs are provided for the different components in Section 13.2 to 13.7.

13.2 GEOMORPHOLOGY

EcoSpecs and TPCs based on the GAI are provided in Section 13.2.1.

13.2.1 EcoSpecs and TPCs relating to GAI monitoring data: PES and REC

Descriptor	EcoSpec	TPC
Bed material composition	Sampling of the dry season bed material at the EWR site (using a sample size of not less than 500 points) should be undertaken at the prescribed intervals (every 5 years) to assess impacts of flow on the bed sediment and therefore as an indication of the change of available habitat for instream biota. Excessive fining of the bed (i.e. decreases in the size of the 16th, 50th and 84th percentiles of the sediment size distribution as indicated to the left) would indicate insufficient flows being delivered to the site to maintain the geomorphological condition. Coarsening of the bed (increasing the sediment sizes) would indicate further elevated flows, bed - armouring and loss of fine - sediment habitat types.	
	D_{16} = 10 mm	D_{16} sediment size must be between 5 - 15 mm
	D_{50} = 50 mm	D_{50} sediment size must be between 30 - 70 mm
	D_{84} = 420 mm	D_{84} sediment size must be between 300 - 500 mm
Channel morphology	Increased flows have caused the banks to erode. Further increases in the depth (or extent as indicated from fixed point photography) of cut banks would be undesirable and represent a TPC, unless associated with a large (1:10 or greater) flood event. Cut banks can be assessed with regular resurveying and analysis of the cross - section at the EWR site and analysis of fixed point photographs.	

Descriptor	EcoSpec	TPC
		Any increase in the depth, steepness or extent of the cut banks at cross section scale.

13.3 PHYSICO - CHEMICAL VARIABLES

TPCs and EcoSpecs are provided in Section 13.3.1 – 13.3.2.

13.3.1 EcoSpecs relating to physico - chemical data: PES and REC

River: Vaal		EWR
Water quality metrics		**EcoSpecs: PES and REC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be < 37 mg/L.
	Na_2SO_4	The 95th percentile of the data must be < 51 mg/L.
	$MgCl_2$	The 95th percentile of the data must be < 51 mg/L.
	$CaCl_2$	The 95th percentile of the data must be < 105 mg/L.
	NaCl	The 95th percentile of the data must be < 389 mg/L.
	$CaSO_4$	The 95th percentile of the data must be < 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be < 85 mS/m.
	pH	The 5th and 95th percentiles of the data must be between 6.5 – 8.0 and 8.0 – 8.8.
	Temperature	Initiate baseline monitoring for this variable.
	Dissolved oxygen	Must be between 7 and 8 mg/L.
	Turbidity	Initiate baseline monitoring for this variable.
Nutrients	TIN	The 50th percentile of the data must be between 0.25 and 0.7 mg/L.
	PO_4 - P	The 50th percentile of the data must be between 0.025 and 0.125 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be between 20 and 30 µg/L.
	Chl - a periphyton	The 50th percentile of the data must be 12 to 84 mg/m^2.
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

13.3.2 TPCs relating to physico - chemical data

River: Vaal		EWR 10
Water quality metrics		**TPC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be < 37 mg/L.
	Na_2SO_4	The 95th percentile of the data must be < 51 mg/L.
	$MgCl_2$	The 95th percentile of the data must be < 51 mg/L.
	$CaCl_2$	The 95th percentile of the data must be < 105 mg/L.
	NaCl	The 95th percentile of the data must be < 389 mg/L.
	$CaSO_4$	The 95th percentile of the data must be < 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be < 85 mS/m.
	pH	The 5th and 95th percentiles of the data must be between 6.5 – 8.0 and 8.0 – 8.8.
	Temperature	Initiate baseline monitoring for this variable.
	Dissolved oxygen	Must be between 7 and 8 mg/L.
Nutrients	TIN	The 50th percentile of the data must be between 0.25 and 0.7 mg/L.
	PO_4 - P	The 50th percentile of the data must be between 0.025 and 0.125 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be between 20 and 30 µg/L.
	Chl - a periphyton	The 50th percentile of the data must be 12 to 84 mg/m^2.
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

13.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the VEGRAI data are provided Section 13.4.1 to 13.4.2.

13.4.1 EcoSpecs and TPCs description relating to VEGRAI monitoring data: PES and REC

PES and REC	Assessed Component	Zone Assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Baseline Note
C	Exotic Invasion (perennial exotics).	Marginal zone.	Maintain perennial exotic species cover below 20%.	An increase in perennial exotic species above 15%.	Same as PES	< 10%, non - woody weeds, but *Myriophyllum aquaticum* present.
		Lower zone.	Maintain perennial exotic species cover below 20%.	An increase in perennial exotic species above 15%.		20 - 40%, non - woody and woody: *Sesbanea punicea.*
		Upper zone.	Maintain perennial exotic species cover below 20%.	An increase in perennial exotic species above 15%.		40 - 60% woody and non - woody: *Morus alba, Salix babylonica, S. punecea.*
	Terrestrial woody species cover.	Marginal zone.	Maintain the absence of terrestrial woody species.	The presence of terrestrial woody species.		No woody terrestrial species were recorded.
		Lower zone.	Maintain cover of terrestrial woody species below 10%.	The presence of terrestrial woody species.		No woody terrestrial species were recorded.
		Upper zone.	Maintain cover of terrestrial woody species below 30%.	An increase in woody terrestrial species covers above 10%.		Approx 10%.
	Indigenous Riparian Woody Cover.	Marginal zone.	Maintain indigenous riparian woody cover below 50%, but retain presence i.e. not 0%.	An absence of riparian woody cover OR an increase above 30%.		< 10%, *Gomphostigma virgatum.*
		Lower zone.	Maintain indigenous riparian woody cover below 30%.	An increase in riparian woody cover above 15%.		< 10%, *G. virgatum.*
		Upper zone.	Maintain indigenous riparian woody cover below 25%.	An increase in riparian woody cover above 15%.		< 10%, *G. virgatum.*
	Non - woody Indigenous Cover (grasses, sedges and dicotyledonous forbs).	Marginal zone.	Maintain non - woody cover above 30%.	A decrease in non - woody cover below 50%.		60 - 80% recorded during VEGRAI assessment.
		Lower zone.	Maintain non - woody cover above 40%.	A decrease in non - woody cover below 50%.		60 - 80% recorded during VEGRAI assessment.
		Upper zone.	Maintain non - woody cover above 20%.	A decrease in non - woody cover below 50%.		80 - 100% recorded during VEGRAI assessment.
	Phragmites (reed) cover.	Riparian zone.	Maintain the absence of reeds.	A presence of reeds.		Reeds were not observed at the site, but occurred in localised reed beds upstream.

13.4.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data: PES and REC

Colour coding in the table below refers to:

EcoSpecs	TPC	Baseline	PES and REC

EC	Perennial Exotics (%)	Terrestrialization (%)	Riparian Woody (%)	Non-woody (%)	Reeds (%)
Marginal Zone					
A	0	0	5 - 10	70 - 80	0
A/B	1 - 5	0	10 - 20	60 - 70; 80 - 90	0
B	5 - 10	0	1 - 5 ; 20 - 30	50 - 60; > 90	0
B/C	10 - 15	0	30 - 40	40 - 50	0
C	15 - 20	0	40 - 50	30 - 40	0
C/D	20 - 30	0	0 ; 50 - 60	20 - 30	1 - 5
D	30 - 50	1 - 5	60 - 70	10 - 20	5 - 10

EC	Perennial Exotics (%)	Terrestrialization (%)	Riparian Woody (%)	Non-woody (%)	Reeds (%)
D/E	50 - 60	5 - 10	70 - 80	1 - 10	10 - 15
E	60 - 70	10 - 15	80 - 90	0	15 - 20
E/F	70 - 80	15 - 20	> 90		20 - 25
F	> 80	> 20			> 25
Lower Zone					
A	0	0	0 - 5	80 - 90	0
A/B	1 - 5	0	5 - 10	70 - 80; > 90	0
B	5 - 10	0	10 - 15	60 - 70	0
B/C	10 - 15	1 - 5	15 - 20	50 - 60	0
C	15 - 20	5 - 10	20 - 30	40 - 50	0
C/D	20 - 30	10 - 15	30 - 40	30 - 40	1 - 10
D	30 - 50	15 - 20	40 - 50	20 - 30	10 - 20
D/E	50 - 60	20 - 30	50 - 60	10 - 20	20 - 30
E	60 - 70	30 - 40	60 - 70	5 - 10	30 - 40
E/F	70 - 80	40 - 50	70 - 80	1 - 5	40 - 50
F	> 80	> 50	> 80		> 50
Upper Zone					
A	0	0 - 5	0 - 5	80 - 90	0
A/B	1 - 5	5 - 10	5 - 10	70 - 80; > 90	0
B	5 - 10	10 - 15	10 - 15	50 - 70	0
B/C	10 - 15	15 - 20	15 - 20	30 - 50	0
C	15 - 20	20 - 30	20 - 25	20 - 30	0
C/D	20 - 30	30 - 40	25 - 30	1 - 20	0
D	30 - 50	40 - 50	30 - 40	0	1 - 5
D/E	50 - 60	50 - 60	40 - 50		5 - 10
E	60 - 70	60 - 70	50 - 60		10 - 15
E/F	70 - 80	70 - 80	60 - 70		15 - 20
F	> 80	> 80	> 70		> 20

13.5 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 13.5.1. The spatial FROC of EWR 10 is provided in Section 13.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

13.5.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES / REC						AEC↑
			EWR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
5	Species richness.	All indigenous species.	Six of an expected ten indigenous fish species to be sampled (as per EWR baseline survey).	Less than five species sampled during any survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity - depth categories and cover features (to be quantified by RHAM if applicable).	All indigenous species.		Baseline (PES) FRAI score of 61% (C/D) calculated for the reach. Any decreased FROC in reach of especially ASCL, BAEN and LCAP (refer to FROC: Table 2[1]) OR FRAI scores decreasing below 57.4% (D).	An improvement from PES FROC in the reach for especially ASCL, BPAL and BKIM should be indicative of reaching/maintaining the improved AEC (refer to FROC sheet for more detail).
4	Relative abundance.	All indigenous species.	Fish sampled at > 1.5 individuals per minute (electrofishing).	Relative abundance of less than 1.1 individual per minute sampled at the site (during same seasons as baseline data) when habitat can be sampled efficiently using electrofishing.	N/A	N/A		N/A	
11	Alien fish species.	Any alien/introduced spp.	Two alien fish species (GAFF and CCAR) present, while MSAL known to be present in this reach. CCAR present 50% of surveys at a relative abundance of 0.06 ind/ivmin and GAFF 100% of time at < 0.13 indiv/min.	Increase in the number of alien species (> 3 species during any survey).	N/A	Any alien/ introduced spp.		Increase in the number of alien species (> 3 species in reach) **OR** presence of any alien species other than CCAR, GAFF and MSAL.	
1	FD habitats, substrate, flow dependant spp (flow alteration), water column.	BAEN, LCAP	BAEN and LCAP sampled 100% of time. BAEN present at relative abundance of > 0.4 indiv/min. and LCAP at relative abundance of > 0.07 indiv/min.	BAEN **OR** LCAP present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.2 indiv/min for BAEN and < 0.03 indiv/min for LCAP.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates, Reduction in suitability of water column (i.e. increased sedimentation of pools). To be quantified with RHAM.	BAEN	LCAP	Any decreased FROC in reach of BAEN and LCAP (refer to FROC, column F: Table 2).	
2	FS habitats.	BAEN	BAEN sampled 100% of time at relative abundance of > 0.4 indiv/min.	BAEN present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.2 indiv/min.	Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows), to be quantified with RHAM.	BAEN	ASCL	Any decreased FROC in reach of BAEN and ASCL (refer to FROC, column F: Table 2).	
3	Water quality intolerance.	LCAP, BANO	LCAP sampled 100% of time at relative abundance of > 0.07 indiv/min. BANO sampled 50% of time at	LCAP present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.03	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	BKIM	BPAL	Any decreased FROC in reach of BKIM and BPAL (refer to FROC, column F: Table 2).	

Rank	Metric	Indicator spp.	PES / REC						AEC↑
			EWR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
			relative abundance 0.1 indiv/min.	indiv/min for LCAP. BANO present less than 50% of time (not sampled for two consecutive surveys).					
6	SD habitats.	CGAR, LCAP	CGAR and LCAP sampled 100% of time. CGAR present at relative abundance of > 0.02 indiv/min and LCAP at relative abundance of > 0.07 indiv/min.	LCAP present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.03 indiv/min for LCAP. CGAR present less than 50% of time (not sampled for two consecutive surveys).	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools). To be quantified with RHAM.	CGAR	LCAP	Any decreased FROC in reach of CGAR and LCAP (refer to FROC, column F: Table 2).	
7	SS habitats.	BANO, PPHI	PPHI sampled 100% of time at relative abundance of > 0.1 indiv/min. BANO sampled 50% of time at relative abundance 0.1 indiv/min.	PPHI present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.05 ind/min. BANO present less than 50% of time (not sampled for two consecutive surveys).	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats). To be quantified with RHAM.	BANO	PPHI	Any decreased FROC in reach of BANO and PPHI (refer to FROC, column F: Table 2).	
9	Overhanging vegetation.	PPHI, TSPA	PPHI and TSPA sampled 100% of time at relative abundance of > 0.1 indiv/min for PPHI and > 0.1 indiv/min for TSPA.	PPHI **AND/OR** TSPA present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.05 indiv/min for PPHI **AND/OR** TSPA.	Significant change in overhanging vegetation habitats (to be quantified with RHAM).	PPHI	TSPA	Any decreased FROC in reach of PPHI and TSPA (refer to FROC, column F: Table 2).	
10	Undercut banks.	PPHI	PPHI sampled 100% of time at relative abundance of > 0.1 indiv/min.	PPHI present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.05 indiv/min.	Significant change in undercut bank habitats (to be quantified with RHAM).	ASCL	PPHI	Any decreased FROC in reach of ASCL and PPHI (refer to FROC, column F: Table 2).	
8	Instream vegetation.	TSPA, BANO	TSPA sampled 100% of time at relative abundance of > 0.1 indiv/min. BANO sampled 50% of time at relative abundance 0.1 indiv/min.	TSPA present less than 100% of time (not sampled during any survey) **AND/OR** decrease in relative abundance of < 0.05 indiv/min AND/OR ANO present less than 50% of time (not sampled for two consecutive surveys).	Significant change in instream vegetation habitats (to be quantified with RHAM).	TSPA	BANO	Any decreased FROC in reach of TSPA and BANO (refer to FROC, column F: Table 2).	

1 Refer to electronic data (DWA, 2010a).

13.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (C/D)		AEC up (C)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
ASCL	*Austroglanis sclateri* (Boulenger, 1901)	4	1	0	2
BAEN	***Labeobarbus aeneus* (Burchell, 1822)**	**4**	**4**	**3**	**4**
BANO	***Barbus anoplus* (Weber, 1897)**	**4**	**2**	**1**	**2**
BPAL	*Barbus pallidus* (Smith, 1841)	3	0		1
BKIM	*Labeobarbus kimberleyensis* (Gilchrist and Thompson, 1913)	3	1	0	2
CGAR	***Clarias gariepinus* (Burchell, 1822)**	**4**	**3**	**2**	**3**
LCAP	***Labeo capensis* (Smith, 1841)**	**4**	**4**	**3**	**4**
LUMB	*Labeo umbratus* (Smith, 1841)	3	1	0	1
PPHI	***Pseudocrenilabrus philander* (Weber, 1897)**	**4**	**4**	**3**	**4**
TSPA	***Tilapia sparrmanii* (Smith, 1840)**	**4**	**4**	**3**	**4**
(species in bold sampled at EWR site during baseline surveys)					

13.6 MACROINVERTEBRATES

13.6.1 Reference Conditions

Reference conditions are based on professional judgment and data collected by Dr Mark Chutter from his Sites 7, 15, 16 and 17 (Chutter, 1967: Table 11). The reference SASS5 Score is 182 and the ASPT is 6.1.

13.6.2 Baseline Description

Baseline biomonitoring data available for EWR 10 are summarised as follows:

Date	SASS5 Score	ASPT	No. of Taxa	Category (Dallas 2007)	MIRAI (%)	PES
10 - 04 - 08	86	5.7	15	C/D	59.3%	C/D
09 - 08 - 07	64	4.9	13	D		

13.6.3 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration, were recorded at the site during baseline sampling, and were selected as monitoring indicators for EWR 10.

Family	Flow				Substrate					Water Quality		
	Standing (<0.1 m/s)	Slow (0.1 - 0.3 m/s)	Mod (0.3 - 0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Vegetation	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7 - 10)	Low (SASS 4 - 6)
Baetidae (>2 spp)	●	●	⬤	⬤	●	●	⬤	●	●		10	
Atyidae (Freshwater shrimps)		●						⬤			8	
Hydropsychidae (2 spp)			●	⬤	●	⬤	●					5
Simuliidae (Blackflies)		●	⬤	⬤	⬤	⬤	⬤	⬤				5
Heptageniidae (Flathead mayflies)		●	●	●		●	⬤	●		13		
Hydropsychidae (>2 spp)			●	⬤	●	⬤	●			12		
Perlidae (Stoneflies)			●	⬤		●	⬤			12		
Psephenidae (Water pennies)			●	⬤		⬤	●				10	
Athericidae		●	⬤			●	⬤	●			10	
Leptophlebiidae (Prongills)	●	⬤	●		●	●	⬤	●	⬤		9	
Tricorythidae (Stout crawlers)			●	⬤	●	⬤	⬤	●			9	
Elmiidae (Riffle beetles)			●	⬤		⬤	●	●			8	
Lestidae	●	●						⬤			8	
Ancylidae	●	●	●	●	●	●	●	●				6
Caenidae (Squaregills)	●	⬤				●	⬤	●	●			6
Dytiscidae (Diving beetles)	⬤	●						⬤				5

● = Partial Preference ⬤ = Strong Preference

The diversity of macroinvertebrate taxa at this site was low, and this limited the selection of suitable monitoring indicators. However, freshwater shrimps were recorded at this site on both sampling occasions during baseline sampling, and therefore provide useful indicators for monitoring. Caddisfly species recorded at the site during baseline sampling included *Cheumatopsyche thomasseti, C. afra,* and *Amphipysche scottae.* Blackfly species recorded in April 2008 were *Simulium adersi* and *S. damnosum.*

13.6.4 EcoSpecs and TPCs relating to the MIRAI data: PES and REC

EcoSpecs and TPCs for the PES and REC (C/D) at EWR 10 are provided below:

ECOSPECS: Biota	TPCS
SASS5 Score between 59 and 90.	SASS5 Score < 67.
ASPT between 4.8 and 5.6.	ASPT < 5.0.
MIRAI Score between 56% and 62%.	MIRAI Score < 57%.
Baetidae > 2 spp.	Baetidae < 2 spp.
Atyidae present.	Atyidae absent on two or more consecutive surveys.
Hydropsychidae > 1 spp.	Hydropsychidae absent.
Simuliidae present.	Simuliidae absent on two or more consecutive surveys.

14 EWR 11: BLESBOKSPRUIT (BLESBOKSPRUIT RIVER)

A summary of the EcoClassification results are provided below (DWA, 2009c).

14.1 ECOCLASSIFICATION SUMMARY OF EWR 11

The aims at EWR 11 are to improve the PES to the REC as the Instream EcoStatus is presently in a D/E which is unacceptable. This is due largely to both the water quality problems, and the increased flows. This was the only scenario investigated.

EWR 11 Blesbokspruit (Blesbokspruit River)

EIS: LOW
Site is characterised by water quality problems and elevated flows.

PES: D
Mainly flow related impacts that include increased base flows and floods due to mine water decants, urban runoff, agriculture and return flows from WWTW. Water quality is also heavily impacted due to these activities and erosion has increased. Alien fish species occur.

REC: D
Maintain the PES due to the **LOW** EIS rating, **with macroinvertebrates improving to D.**

An improved EcoStatus based on a hypothetical flow regime is not feasible at this site. Decreased flows as a scenario is possible and will result in deteriorated water quality.

The improvement of the macroinvertebrate EC is only possible with improved water quality. Improved water quality is only possible with better water quality management, which is unlikely, but feasible at a cost. Due to the huge amount of salts in the system, this improvement will only be a long term option.

The implications for setting flows are the following:
Flow requirements to maintain the present state would be based on present flows. Only increased flows can be evaluated as a scenario to determine whether increased flows (with either improved or the same water quality) will maintain the EcoStatus.

Driver Components	PES Category	Trend	REC
HYDROLOGY	D/E		
WATER QUALITY	D/E	Negative D/E	D
GEOMORPHOLOGY	C	Negative C/D	C
Response Components	**PES Category**	**Trend**	**REC**
FISH	D	Stable	C
MACRO INVERTEBRATES	D/E	Stable	D
INSTREAM	D/E		C/D
RIPARIAN VEGETATION	D	Negative D/E	D
ECOSTATUS	D		D

EcoSpecs and TPCs are provided for the different components in Section 14.2 to 14.7.

14.2 GEOMORPHOLOGY

EcoSpecs and TPCs based on the GAI are provided in Section 14.2.1.

14.2.1 EcoSpecs and TPCs relating to GAI monitoring data: PES

Descriptor	EcoSpec	TPC
Bed material composition	Sampling of the dry season bed material at the EWR site (using a sample size of not less than 500 points) should be undertaken at the prescribed intervals (every 5 years) to assess impacts of flow on the bed sediment and therefore as an indication of the change of available habitat for instream biota. Excessive fining of the bed (i.e. decreases in the size of the 16th, 50th and 84th percentiles of the sediment size distribution as indicated to the left) would indicate insufficient flows being delivered to the site to maintain the geomorphological condition. Coarsening of the bed (increasing the sediment sizes) would indicate further elevated flows, bed - armouring and loss of fine - sediment habitat types.	
	D_{16} = 2 mm	D_{16} sediment size must be between 1 - 5 mm

Descriptor	EcoSpec	TPC
	D_{50} = 80 mm	D_{50} sediment size must be between 50 - 100 mm
	D_{84} = 360 mm	D_{84} sediment size must be between 250 - 450 mm
Channel morphology	Increased flows have caused the banks to erode. Further increases in the depth (or extent as indicated from fixed point photography) of cut banks would be undesirable and represent a TPC, unless associated with a large (1:10 or greater) flood event. Cut banks can be assessed with regular resurveying and analysis of the cross - section at the EWR site and analysis of fixed point photographs.	
		Any widening or deepening of the active channel at cross section scale.

14.3 PHYSICO - CHEMICAL VARIABLES

TPCs and EcoSpecs are provided in Section 14.3.1 – 14.3.2.

14.3.1 EcoSpecs relating to physico - chemical data: PES and REC

River: Vaal		EWR 11
Water quality metrics		**EcoSpecs: PES and REC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be < 45 mg/L.
	Na_2SO_4	The 95th percentile of the data must be < 64 mg/L.
	$MgCl_2$	The 95th percentile of the data must be < 66 mg/L.
	$CaCl_2$	The 95th percentile of the data must be < 141 mg/L.
	NaCl	The 95th percentile of the data must be < 535 mg/L.
	$CaSO_4$	The 95th percentile of the data must be < 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be < 85 mS/m.
	pH	The 5th and 95th percentiles of the data must be between 6.5 – 8.0 and 8.0 – 8.8.
	Temperature	Initiate baseline monitoring for this variable.
	Dissolved oxygen	Must be between 7 and 8 mg/L.
	Turbidity	Initiate baseline monitoring for this variable.
Nutrients	TIN	The 50th percentile of the data must be between 0.25 and 0.7 mg/L.
	PO_4 - P	The 50th percentile of the data must be between 0.025 and 0.125 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be between 20 and 30 µg/L.
	Chl - a periphyton	The 50th percentile of the data must be 12 to 84 mg/m^2.
	Toxics	An impact is expected if the 95th percentile of the data exceeds the TWQR as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

14.3.2 TPCs relating to physico - chemical data

River: Vaal		EWR11
Water quality metrics		**TPC**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be < 45 mg/L.
	Na_2SO_4	The 95th percentile of the data must be < 64 mg/L.
	$MgCl_2$	The 95th percentile of the data must be < 66 mg/L.
	$CaCl_2$	The 95th percentile of the data must be < 141 mg/L.
	NaCl	The 95th percentile of the data must be < 535 mg/L.
	$CaSO_4$	The 95th percentile of the data must be < 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be < 85 mS/m.
	pH	The 5th and 95th percentiles of the data must be between 6.5 – 8.0 and 8.0 – 8.8.
	Temperature	Initiate baseline monitoring for this variable.
	Dissolved oxygen	Must be between 7 and 8 mg/L.
Nutrients	TIN	The 50th percentile of the data must be between 0.25 and 0.7 mg/L.

River: Vaal		EWR11
Water quality metrics		TPC
	PO_4 - P	The 50th percentile of the data must be between 0.025 and 0.125 mg/L.
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be between 20 and 30 µg/L.
	Chl - a periphyton	The 50th percentile of the data must be 12 to 84 mg/m^2.
	Toxics	An impact is expected if the 95th percentile of the data exceeds the TWQR as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution expected.

14.4 RIPARIAN VEGETATION

EcoSpecs and TPCs based on the VEGRAI data are provided Section 14.4.1 to 14.4.2.

14.4.1 EcoSpecs and TPCs description relating to VEGRAI monitoring data: PES and REC

PES and REC	Assessed Component	Zone Assessed	EcoSpec (PES)	TPC (PES)	EcoSpec (REC)	Baseline Note
D	Exotic Invasion (perennial exotics).	Marginal Zone.	Maintain perennial exotic species cover below 50%.	An increase in perennial exotic species above 10%.	Same as PES	< 10%, non - woody weeds.
		Lower zone.	Maintain perennial exotic species cover below 50%.	An increase in perennial exotic species above 20%.		10 - 20%, non - woody and woody: *Sesbanea punicea, Salix babylonica,* Birch.
		Upper Zone.	Maintain perennial exotic species cover below 50%.	An increase in perennial exotic species above 20%.		< 10%, woody and non - woody.
	Terrestrial woody species cover.	Marginal zone.	Maintain cover of terrestrial woody species below 5%.	The presence of terrestrial woody species.		No woody terrestrial species were recorded.
		Lower zone.	Maintain cover of terrestrial woody species below 20%.	An increase in woody terrestrial species covers above 10%.		No woody terrestrial species were recorded.
		Upper Zone.	Maintain cover of terrestrial woody species below 50%.	An increase in woody terrestrial species covers above 20%.		5 - 10%, *D. lycioides.*
	Indigenous Riparian Woody Cover.	Marginal Zone.	Maintain indigenous riparian woody cover below 70%.	An absence of riparian woody cover OR an increase above 50%.		No indigenous riparian woody species recorded during VEGRAI assessment.
		Lower Zone.	Maintain indigenous riparian woody cover below 50%.	An increase in riparian woody cover above 30%.		No indigenous riparian woody species recorded during VEGRAI assessment.
		Upper Zone.	Maintain indigenous riparian woody cover below 40%.	An increase in riparian woody cover above 20%.		No indigenous riparian woody species recorded during VEGRAI assessment.
	Non - woody Indigenous Cover (grasses, sedges and dicotyledonous forbs).	Marginal Zone.	Maintain non - woody cover above 10%.	A decrease in non - woody cover below 30%.		40 - 60% recorded during VEGRAI assessment.
		Lower Zone.	Maintain non - woody cover above 20%.	A decrease in non - woody cover below 40%.		40 - 60% recorded during VEGRAI assessment.
		Upper Zone.	Maintain non - woody cover above 0%.	A decrease in non - woody cover below 20%.		80 - 100% recorded during VEGRAI assessment.
	Phragmites (reed) cover.	Marginal Zone.	Maintain reed cover below 10%.	An increase in reed cover above 10%.		About 10% cover.
		Lower Zone.	Maintain reed cover below 20%.	An increase in reed cover above 10%.		About 10% cover.
		Upper Zone.	Maintain reed cover below 5%.	A presence of reeds.		Not recorded.

14.4.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data: PES and REC

Colour coding in the table below refers to:

EcoSpecs	TPC	Baseline	PES and REC

EC	Perennial Exotics (%)	Terrestrialization (%)	Riparian Woody (%)	Non-woody (%)	Reeds (%)
Marginal Zone					
A	0	0	5 - 10	70 - 80	0
A/B	1 - 5	0	10 - 20	60 - 70; 80 - 90	0
B	5 - 10	0	1 - 5 ; 20 - 30	50 - 60; > 90	0
B/C	10 - 15	0	30 - 40	40 - 50	0
C	15 - 20	0	40 - 50	30 - 40	0
C/D	20 - 30	0	0 ; 50 - 60	20 - 30	1 - 5
D	30 - 50	1 - 5	60 - 70	10 - 20	5 - 10
D/E	50 - 60	5 - 10	70 - 80	1 - 10	10 - 15
E	60 - 70	10 - 15	80 - 90	0	15 - 20
E/F	70 - 80	15 - 20	> 90		20 - 25
F	> 80	> 20			> 25
Lower Zone					
A	0	0	0 - 5	80 - 90	0
A/B	1 - 5	0	5 - 10	70 - 80; > 90	0
B	5 - 10	0	10 - 15	60 - 70	0
B/C	10 - 15	1 - 5	15 - 20	50 - 60	0
C	15 - 20	5 - 10	20 - 30	40 - 50	0
C/D	20 - 30	10 - 15	30 - 40	30 - 40	1 - 10
D	30 - 50	15 - 20	40 - 50	20 - 30	10 - 20
D/E	50 - 60	20 - 30	50 - 60	10 - 20	20 - 30
E	60 - 70	30 - 40	60 - 70	5 - 10	30 - 40
E/F	70 - 80	40 - 50	70 - 80	1 - 5	40 - 50
F	> 80	> 50	> 80		> 50
Upper Zone					
A	0	0 - 5	0 - 5	80 - 90	0
A/B	1 - 5	5 - 10	5 - 10	70 - 80; > 90	0
B	5 - 10	10 - 15	10 - 15	50 - 70	0
B/C	10 - 15	15 - 20	15 - 20	30 - 50	0
C	15 - 20	20 - 30	20 - 25	20 - 30	0
C/D	20 - 30	30 - 40	25 - 30	1 - 20	0
D	30 - 50	40 - 50	30 - 40	0	1 - 5
D/E	50 - 60	50 - 60	40 - 50		5 - 10
E	60 - 70	60 - 70	50 - 60		10 - 15
E/F	70 - 80	70 - 80	60 - 70		15 - 20
F	> 80	> 80	> 70		> 20

14.5 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 14.5.1. The spatial FROC of EWR 11 is provided in Section 14.5.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

14.5.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES					REC
			EWR SITE			REACH		REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
5	Species richness.	All indigenous species.	Four of an expected ten indigenous fish to be sampled (as per EWR baseline survey).	Less than two species sampled during any survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity - depth categories and cover features (to be quantified by RHAM if applicable).	All indigenous species.	Baseline (PES) FRAI score of 44.8% (D) calculated for the reach. Any decreased FROC in reach of especially BAEN and PPHI (refer to FROC: Table 2[1]) OR FRAI scores decreasing below 42.02% (D/E).	An improvement from PES FROC in the reach for especially ASCL, BPAL, BKIM, LCAP and LUMB should be indicative of reaching/maintaining the REC (refer to FROC sheet for more detail).
4	Relative abundance.	All indigenous species.	Fish sampled at > 0.03 individuals per minute (electrofishing).	Relative abundance of less than 0.02 individual per minute sampled at the site (during same seasons as baseline data) when habitat can be sampled efficiently using electrofishing.	N/A	N/A	N/A	
10	Alien fish species.	Any alien/introduced spp.	Two alien fish species (GAFF and CCAR) sampled at site 50% of time. CCAR present at a relative abundance of < 0.04 indiv/min and GAFF at 0.02 indiv/min.	Increase in the number of alien species (> 2 species during any survey).	N/A	Any alien/introduced spp.	Increase in the number of alien species (> 2 species in reach) **OR** presence of any alien species other than CCAR, and GAFF.	
1	FD and FS habitats, substrate, flow dependant spp (flow alteration), water quality intolerance.	BAEN	BAEN sampled 50% of time at relative abundance of > 0.6 indiv/min.	BAEN present less than 50% of time (not sampled during two consecutive surveys).	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows), Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates (to be quantified with RHAM). Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	BAEN	Any decreased FROC in reach of BAEN (refer to FROC, column F: Table 2).	
3	SD habitats.	CGAR, BAEN	BAEN and CGAR sampled 50% of time at relative abundance of > 0.6 indiv/min for BAEN and > 0.01 indiv/min for CGAR.	BAEN **AND/OR** CGAR present less than 50% of time (not sampled during two consecutive surveys).	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools). [To be quantified with RHAM].	CGAR BAEN	Any decreased FROC in reach of CGAR and BAEN (refer to FROC, column F: Table 2).	
2	Water column.	BAEN, BPAU	BAEN sampled 50% of time at relative abundance of > 0.6 indiv/min. BPAU sampled 100% of time at	BPAU present less than 100% of time (not sampled during any survey) **AND/OR** present at relative abundance below 0.005 ind/min	Reduction in suitability of water column (i.e. increased sedimentation of pools) [to be quantified with RHAM].	BAEN BPAU	Any decreased FROC in reach of BAEN and BPAU (refer to FROC, column F: Table 2).	

Rank	Metric	Indicator spp.	PES						REC
			EWR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
			relative abundance > 0.01 indiv/min.	**AND/OR** BAEN present less than 50% of time (not sampled during two consecutive surveys).					
8	SS habitats.	PPHI, CGAR	PPHI and CGAR sampled 50% of time at relative abundance of > 0.01 indiv/min for both these species.	PPHI **AND/OR** CGAR present less than 50% of time (not sampled during two consecutive surveys).	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats). (To be quantified with RHAM).	BANO	PPHI	Any decreased FROC in reach of BANO and PPHI (refer to FROC, column F: Table 2).	
6	Overhanging vegetation.	PPHI, BPAU	PPHI sampled 50% of time at relative abundance of > 0.01 indiv/min. BPAU sampled 100% of time at relative abundance > 0.01 indiv/min.	BPAU present less than 100% of time (not sampled during any survey) **AND/OR** present at relative abundance below 0.005 indiv/min AND/**OR** PPHI present less than 50% of time (not sampled during two consecutive surveys).	Significant change in overhanging vegetation habitats (to be quantified with RHAM).	PPHI	TSPA	Any decreased FROC in reach of PPHI and TSPA (refer to FROC, column F: Table 2).	
9	Undercut banks.	PPHI	PPHI sampled 50% of time at relative abundance of > 0.01 indiv/min.	PPHI present less than 50% of time (not sampled during two consecutive surveys).	Significant change in undercut bank habitats (to be quantified with RHAM).	PPHI		Any decreased FROC in reach of PPHI (refer to FROC, column F: Table 2).	
7	Instream vegetation.	BPAU	BPAU sampled 100% of time at relative abundance > 0.01 indiv/min.	BPAU present less than 100% of time (not sampled during any survey) **AND/OR** present at relative abundance below 0.005 indiv/min.	Significant change in instream vegetation habitats (to be quantified with RHAM).	TSPA	BANO	Any decreased FROC in reach of TSPA and BANO (refer to FROC, column F: Table 2).	

1 Refer to electronic data (DWA, 2010a).

14.5.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (D)		REC (C)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
ASCL	*Austroglanis sclateri* (Boulenger, 1901)	2	0		1
BAEN	***Labeobarbus aeneus* (Burchell, 1822)**	**4**	**3**	**2**	**3**
BANO	*Barbus anoplus* (Weber, 1897)	4	2	1	2
BPAL	*Barbus pallidus* (Smith, 1841)	3	1	0	2
BPAU	***Barbus paludinosus* (Peters, 1852)**	**3**	**2**	**1**	**2**
CGAR	***Clarias gariepinus* (Burchell, 1822)**	**4**	**3**	**2**	**3**
LCAP	*Labeo capensis* (Smith, 1841)	4	0		2
LUMB	*Labeo umbratus* (Smith, 1841)	3	0		2
PPHI	***Pseudocrenilabrus philander* (Weber, 1897)**	**4**	**4**	**3**	**4**
TSPA	*Tilapia sparrmanii* (Smith, 1840)	4	4	3	4
(species in bold sampled at EWR site during baseline surveys)					

14.6 MACROINVERTEBRATES

14.6.1 Reference Conditions

Reference conditions are based on professional judgment and data collected by Dr Mark Chutter from his Sites 15 and 16 (Chutter, 1967: Table 11). The reference SASS5 Score is 164 and the ASPT is 5.9.

14.6.2 Baseline Description

Baseline biomonitoring data available for EWR 11 are summarised as follows:

Date	SASS5 Score	ASPT	No. of Taxa	Category (Dallas 2007)	MIRAI (%)	PES
12 - 04 - 08	61	3.8	16	E	39.8%	D/E
09 - 08 - 07	57	4.1	14	E		

14.6.3 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration, were recorded at the site during baseline sampling, and were selected as monitoring indicators for EWR 11.

Family	Flow				Substrate					Water Quality		
	Standing (<0.1 m/s)	Slow (0.1 - 0.3 m/s)	Mod (0.3 - 0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Vegetation	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7 - 10)	Low (SASS 4 - 6)
Baetidae (2 spp)	●	●	⬤	⬤	●	●	⬤	●	●		10	
Ancylidae	●	●	●	●	●	●	●	●				6
Simuliidae (Blackflies)		●	⬤	⬤	⬤	⬤	⬤	⬤				5
Heptageniidae (Flathead mayflies)		●	●	●		●	⬤	●		13		
Hydropsychidae (>2 spp)			●	⬤	●	⬤	●			12		
Perlidae (Stoneflies)			●	⬤		●	⬤			12		
Psephenidae (Water pennies)			●	⬤		⬤	●				10	
Athericidae		●	⬤			●	⬤	●			10	
Leptophlebiidae (Prongills)	●	⬤	●		●	●	⬤	●	⬤		9	
Tricorythidae (Stout crawlers)			●	⬤	●	⬤	⬤	●			9	
Atyidae (Freshwater shrimps)		●						⬤			8	
Elmiidae (Riffle beetles)			●	⬤		⬤	●	●			8	
Lestidae	●	●						⬤			8	
Caenidae (Squaregills)	●	⬤				●	⬤	●	●			6
Hydropsychidae (2 spp)			●	⬤	●	⬤	●					5
Dytiscidae (Diving beetles)	⬤	●						⬤				5

● = Partial Preference ⬤ = Strong Preference

The diversity of macroinvertebrate taxa at this site was very low, and this limited the selection of suitable monitoring indicators. Only one family of mayflies (Baetidae), one species of caddisfly (*Cheumatopsyche thomasseti*), and one species of blackfly (*Simulium adersi*), were recorded during baseline sampling. Limpets (Ancylidae) were recorded on both sampling occasions during baseline sampling, and therefore provide useful monitoring indicators.

14.6.4 EcoSpecs and TPCs: PES and REC

EcoSpecs and TPCs for the PES (D/E) at EWR 11 are provided below

ECOSPECS: Biota	TPCS
SASS5 Score between 98 and 113.	SASS5 Score < 105.
ASPT between 5.2 and 5.5.	ASPT < 5.3.
MIRAI Score between 40% and 47%.	MIRAI Score < 42%.
Baetidae > 2 spp.	Baetidae < 2 spp.
Ancylidae present.	Ancylidae absent from two or more consecutive surveys.
Simuliidae present.	Simuliidae absent on two or more consecutive surveys.

EcoSpecs and TPCs for the REC (D) at EWR 11 are provided below.

ECOSPECS: Biota	TPCS
SASS5 Score between 113 and 125.	SASS5 Score < 117.
ASPT between 5.4 and 5.7.	ASPT < 5.5.
MIRAI Score between 47% and 57%.	MIRAI Score < 50%.
Baetidae > 2 spp.	Baetidae < 2 spp.
Ancylidae present.	Ancylidae absent from two or more consecutive surveys.
Simuliidae present.	Simuliidae absent on two or more consecutive surveys.

15 RE-EWR 1: KLEIN VAAL (KLEIN VAAL RIVER)

RE-EWR 1 was assessed at a Rapid Reserve level and therefore information is available for fish and macroinvertebrates only. A summary of the EcoClassification results are provided below (DWA, 2009c).

RE-EWR 1: Klein Vaal (Klein Vaal River)

EIS: MODERATE
PES: C
Flow related impacts include interbasin transfer and abstraction altering hydrological regime. Non - flow related impacts include deterioration in water quality, increased erosion due to cattle and agricultural activities. Loss of habitat due to farm dams.

REC: C
Maintain the PES due to the **MODERATE** EIS rating.
The C EcoStatus is due to the riparian vegetation EC of a D as the instream EC is an A/B. The riparian vegetation PES is due to non - flow related impacts (grazing and trampling) and highly likely a very localised impact.

AEC down: C/D
A hydrological regime with decreased base flows.
Increased periods of zero flows during dry season.

IHI			Driver Components	PES and REC Category	AEC↓
INSTREAM	B	RIPARIAN B	HYDROLOGY	A/B	
			WATER QUALITY	B/C	B/C
			GEOMORPHOLOGY	B/C	B/C
			Response Components	PES Category	REC
			FISH	B	C
			MACRO INVERTEBRATES	A/B	C
			INSTREAM	A/B	C
			RIPARIAN VEGETATION	D	D
			ECOSTATUS	C	C/D

IHI Hydro	Diatoms
A/B	B

15.1 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 15.1.1. The spatial FROC of RE-EWR 1 is provided in Section 15.1.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

15.1.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES					REC
			EWR SITE			REACH		REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
5	Species richness.	All indigenous species	Two of the expected seven indigenous fish species to be sampled (as per EWR baseline survey).	Less than two fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity - depth categories and cover features (to be quantified by RHAM).	All indigenous species.	Baseline (PES) FRAI score of 87.1 (B) calculated for the reach. Any decreased FROC in reach of especially BAEN, LCAP, BANO, TSPA and PPHI (refer to FROC: Table 2[1]) OR FRAI scores decreasing below 82.02% (category B/C).	Same as PES
4	Relative abundance.	N/A	Fish sampled at 0.6 individuals per minute.	Relative abundance of less than 0.3 individual per minute sampled at the site (during same season as baseline data) when habitat can be sampled efficiently.	N/A	N/A	N/A	
6	Alien fish species.	Any alien/introduced spp.	No alien fish.	Presence of any alien/introduced fish species at site during any survey.	N/A	Any alien/introduced spp.	MSAL known to be present in reach. An increase in the number of alien species (> 1) or presence of any alien species other than MSAL.	
2	FD, FS habitats, substrate, Flow dependant spp (flow alteration), water column.	BAEN	BAEN present at a relative abundance of 0.5 indiv/min (electrofishing).	BAEN absent during any survey or present at a relative abundance < 0.25 indiv/min (under similar conditions/season as baseline survey).	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows), Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates, Reduction in suitability of water column (i.e. increased sedimentation of pools) [to be quantified with RHAM].	BAEN LCAP	Any decreased FROC in reach of BAEN and LCAP (refer to FROC, column F: Table 2).	
3	Water quality intolerance.	BANO	BANO present at a relative abundance of 0.1 indiv/min (electrofishing).	BANO absent during any survey or present at a relative abundance < 0.05 indiv/min (under similar conditions/season as baseline survey).	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	BPAL BANO	Any decreased FROC in reach of BPAL and BANO (refer to FROC, column F: Table 2).	
1	SD habitats.	BANO, BAEN	BAEN present at a relative abundance of 0.5 indiv/min (electrofishing). BANO present at a relative abundance of 0.1 indiv/min (electrofishing).	BAEN absent during any survey or present at a relative abundance < 0.25 indiv/min (under similar conditions/season as baseline survey). BANO absent during any survey or present at a relative abundance < 0.05 indiv/min (under similar	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools). [To be quantified with RHAM].	BANO LCAP	Any decreased FROC in reach of BBANO and LCAP (refer to FROC, column F: Table 2).	

Rank	Metric	Indicator spp.	PES						REC
			EWR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
				conditions/season as baseline survey).					
3	SS habitats, overhanging vegetation.	BANO	BANO present at a relative abundance of 0.1 indiv/min (electrofishing).	BANO absent during any survey or present at a relative abundance < 0.05 indiv/min (under similar conditions/season as baseline survey).	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats), Significant change in overhanging vegetation habitats (to be quantified with RHAM).	BANO	PPHI	Any decreased FROC in reach of BANO and PPHI (refer to FROC, column F: Table 2).	
7	Undercut banks.	No indicators of undercut banks sampled at site (could be included in future if sampled).				PPHI		Any decreased FROC in reach of PPHI (refer to FROC, column F: Table 2).	
3	Instream vegetation.	BANO	BANO present at a relative abundance of 0.1 indiv/min (electrofishing).	BANO absent during any survey or present at a relative abundance < 0.05 indiv/min (under similar conditions/season as baseline survey).	Significant change in instream vegetation habitats (to be quantified with RHAM).	BANO	TSPA	Any decreased FROC in reach of BANO and TSPA (refer to FROC, column F: Table 2).	

1 Refer to electronic data (DWA, 2010a).

15.1.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (B)		REC (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
BANO	***Barbus anoplus* (Weber, 1897)**	**4**	**3**	**2**	**Same as PES**
BAEN	***Labeobarbus aeneus* (Burchell, 1822)**	**3**	**3**	**2**	
LCAP	*Labeo capensis* (Smith, 1841)	3	2	1	
TSPA	*Tilapia sparrmanii* (Smith, 1840)	3	2	1	
BPAL	*Barbus pallidus* (Smith, 1841)	3	1	0	
LUMB	*Labeo umbratus* (Smith, 1841)	1	1	0	
PPHI	*Pseudocrenilabrus philander* (Weber, 1897)	4	3	2	
(species in bold sampled at EWR site during baseline surveys)					

15.2 MACROINVERTEBRATES

15.2.1 Reference Conditions

Reference conditions are based on professional judgment and data collected by Dr Mark Chutter from his Sites 21 and 21A (Chutter, 1967: Table 11). The reference SASS5 Score is 179 and the ASPT is 6.4.

15.2.2 Baseline Description

Baseline biomonitoring data available for RE-EWR 1 are summarised as follows:

Date	SASS5 Score	ASPT	No. of Taxa	Category (Dallas 2007)	MIRAI (%)	PES
20 - 09 - 07	152	6.3	24	B	90.8%	A/B

15.2.3 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration, were recorded at the site during baseline sampling, and were selected as monitoring indicators for RE-EWR 1:

Family	Flow				Substrate					Water Quality		
	Standing (<0.1 m/s)	Slow (0.1 - 0.3 m/s)	Mod (0.3 - 0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Vegetation	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7 - 10)	Low (SASS 4 - 6)
Heptageniidae (Flathead mayflies)		●	●	●		●	●	●		**13**		
Hydropsychidae (>2 spp)			●	●	●	●	●			**12**		
Leptophlebiidae (Prongills)	●	●	●		●	●	●	●	●		**9**	
Perlidae (Stoneflies)			●	●		●	●			**12**		
Baetidae (>2 spp)	●	●	●	●	●	●	●	●	●		**10**	

Family	Flow				Substrate					Water Quality		
	Standing (<0.1 m/s)	Slow (0.1 - 0.3 m/s)	Mod (0.3 - 0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Vegetation	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7 - 10)	Low (SASS 4 - 6)
Psephenidae (Water pennies)			●	⬤		⬤	●				10	
Athericidae		●	⬤			●	⬤	●			10	
Tricorythidae (Stout crawlers)			●	⬤	●	⬤	⬤	●			9	
Atyidae (Freshwater shrimps)		●						⬤			8	
Elmiidae (Riffle beetles)			●	⬤		⬤	●	●			8	
Lestidae	●	●						⬤			8	
Ancylidae	●	●	●	●	●	●	●	●				6
Caenidae (Squaregills)	●	⬤				●	⬤	●	●			6
Hydropsychidae (2 spp)			●	⬤	●	⬤	●					5
Simuliidae (Blackflies)		●	⬤	⬤	⬤	⬤	⬤	⬤				5
Dytiscidae (Diving beetles)	⬤	●						⬤				5

● = Partial Preference ⬤ = Strong Preference

15.2.4 EcoSpecs and TPCs relating to the MIRAI data: PES and REC

EcoSpecs and TPCs for the PES and REC (A/B) at RE-EWR 1 are provided below:

ECOSPECS: Biota	TPCS
SASS5 Score between 140 and 180.	SASS5 Score < 145.
ASPT between 6.3 and 6.8.	ASPT < 6.4.
MIRAI Score between 86% and 92%.	MIRAI Score < 88%.
To ensure that no group consistently dominates the fauna, defined as C abundance (> 100) over two consecutive surveys.	Any taxon abundance 'D' (> 1000) in two consecutive surveys.
Heptageniidae present.	Heptageniidae absent on two or more consecutive surveys.
Hydropsychidae > 2 spp.	Hydropsychidae < 2 spp.
Leptophlebiidae present.	Leptophlebiidae absent from two or more consecutive surveys.

16 RE-EWR 2: MOOI RIVER (MOOI RIVER)

RE-EWR 2 was assessed at a Rapid Reserve level and therefore information is available for fish and macroinvertebrates only. A summary of the EcoClassification results are provided below (DWA, 2009c).

RE-EWR 2: Mooi River (Mooi River)

EIS: LOW

PES: D

This naturally would have been a wetland with a badly defined channel. Wetland tools were used to represent the driver state and the river tools used to assess the responses.

Some very rare constricted areas with small riffles occur. This site is downstream of the dam and about the only one with remnants of wetland intact. This is a short section. The rest of the MRU is very badly degraded and would be in a lower category. Downstream of the Wonderfontein inflow, the bad water quality would be the overriding concern. The PES is in a D and the rest of the MRU would be in an E or even lower. It will not be possible to improve the category by improving flows as the fish is already in a C EC and the riparian vegetation EC is due to non - flow related impacts. However, the macroinvertebrate EC might improve to at least a D with some improved flow.

Driver Components	PES Category
HYDROLOGY	E
WATER QUALITY	C/D
WETLAND HABITAT INTEGRITY	E
Response Components	**PES Category**
FISH	C
MACRO INVERTEBRATES	E
INSTREAM	D
RIPARIAN VEGETATION	D
ECOSTATUS	D

16.1 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 16.1.1. The spatial FROC of RE-EWR 2 is provided in Section 16.1.2 and indicates the FROC under reference, PES conditions as well as TPCs for baseline (PES) conditions.

16.1.1 EcoSpecs and TPCs relating to FRAI data: PES

Rank	Metric	Indicator spp.	PES					REC
			EWR SITE		REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
5	Species richness.	All indigenous species	Three of an expected eight indigenous fish species to be sampled (as per EWR baseline survey).	Less than 3 fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity - depth categories and cover features (to be quantified by RHAM).	All indigenous species.	Baseline (PES) FRAI score of 62.4% (C) calculated for the reach. Any decreased FROC in reach of especially BPAL, AJOH, TSPA, PPHI (refer to FROC: Table 2[1]) OR FRAI scores decreasing below 60% (category C/D).	Not applicable (Rapid Reserve)
4	Relative abundance.	N/A	Fish sampled at 0.26 individuals per minute.	Relative abundance of less than 0.15 individual per minute sampled at the site (during same season as baseline data) when habitat can be sampled efficiently.	N/A	N/A	N/A	
6	Alien fish species.	Any alien/introduced spp.	No alien fish species sampled.	Presence of any alien/introduced fish species at site during any survey.	N/A	Any alien/introduced spp.	MDOL, MSAL and CCAR known to be present in the reach. Increase in the number of alien fish species (> 3) or presence of any species other than MSAL, MDOL and CCAR.	
	FD, FS habitats.	No indicator species for FD and FS present in the reach.						
2	Substrate.	BPAL	BPAL sampled at a relative abundance of 0.06 indiv/min.	Absence of BPAL during any survey or present at relative abundance < 0.03 indiv/min (electrofishing).	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates. To be quantified with RHAM.	BPAL	Any decreased FROC in reach of BPAL (refer to FROC, column F: Table 2).	
	Flow dependant spp (flow alteration).	No species intolerant or moderately intolerant to flow changes present in reach.						
1	Water quality intolerance.	BPAL, AJOH	BPAL sampled at a relative abundance of 0.06 indiv/min. AJOH sampled at relative abundance of 0.16 indiv/min.	Absence of BPAL **AND/OR** AJOH during any survey **OR** BPAL present at relative abundance < 0.03 indiv/min and AJOH < 0.1 indiv/min (electrofishing).	Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments).	BPAL / AJOH	Any decreased FROC in reach of BPAL and AJOH (refer to FROC, column F: Table 2).	

Rank	Metric	Indicator spp.	PES					REC
			EWR SITE		REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
2	SD habitats.	BANO, AJOH	BANO sampled at a relative abundance of 0.03 indiv/min. AJOH sampled at relative abundance of 0.16 indiv/min.	Absence of BANO AND/OR AJOH during any survey **OR** BANO present at relative abundance < 0.01 indiv/min and AJOH < 0.1 indiv/min (electrofishing).	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools). To be quantified with RHAM.	CGAR, BANO	Any decreased FROC in reach of CGAR and BANO (refer to FROC, column F: Table 2).	
7	Water column.	No indicator species for water column sampled at site				BPAU	Any decreased FROC in reach of BPAU (refer to FROC, column F: Table 2).	
2	SS habitats.	BANO, BPAL	BANO sampled at a relative abundance of 0.03 indiv/min. BPAL sampled at a relative abundance of 0.06 indiv/min.	Absence of BANO AND/OR BPAL during any survey **OR** BANO present at relative abundance < 0.01 indiv/min and BPAL at relative abundance < 0.03 indiv/min.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats). To be quantified with RHAM.	BANO, PPHI	Any decreased FROC in reach of BANO and PPHI (refer to FROC, column F: Table 2).	
2	Overhanging vegetation.	BANO, AJOH	BANO sampled at a relative abundance of 0.03 indiv/min. AJOH sampled at relative abundance of 0.16 indiv/min.	Absence of BANO AND/OR AJOH during any survey **OR** BANO present at relative abundance < 0.01 indiv/min and AJOH < 0.1 indiv/min (electrofishing).	Significant change in overhanging vegetation habitats (to be quantified with RHAM).	PPHI, TSPA	Any decreased FROC in reach of PPHI and TSPA (refer to FROC, column F: Table 2).	
8	Undercut banks.	No indicator species for undercut banks sampled at site.				PPHI	Any decreased FROC in reach of PPHI (refer to FROC, column F: Table 2).	
3	Instream vegetation.	BANO	BANO sampled at a relative abundance of 0.03 indiv/min.	Absence of BANO during any survey **OR** BANO present at relative abundance < 0.01 indiv/min.	Significant change in instream vegetation habitats (to be quantified with RHAM).	TSPA, BANO	Any decreased FROC in reach of TSPA and BANO (refer to FROC, column F: Table 2).	

1 Refer to electronic data (DWA, 2010a).

16.1.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES (C)		REC (C)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
BANO	***Barbus anoplus* (Weber, 1897)**	**4**	**3**	**2**	**Same as PES**
BPAL	***Barbus pallidus* (Smith, 1841)**	**3**	**2**	**1**	
BPAU	*Barbus paludinosus* (Peters, 1852)	3	1	0	
BTRI	*Barbus trimaculatus* (Peters, 1852)	3	1	0	
CGAR	*Clarias gariepinus* (Burchell, 1822)	4	4	3	
PPHI	*Pseudocrenilabrus philander* (Weber, 1897)	4	3	2	
TSPA	*Tilapia sparrmanii* (Smith, 1840)	4	3	2	
AJOH	***Aplocheilichthys johnstoni* (Günther, 1893)**	**2**	**1**	**0**	
(species in bold sampled at EWR site during baseline surveys)					

16.2 MACROINVERTEBRATES

16.2.1 Reference Conditions

Reference conditions are based on professional judgment and data collected by Dr Mark Chutter from his Sites 7, 15, 16 and 17 (Chutter, 1967: Table 11). The reference SASS5 Score is 145 and the ASPT is 6.0.

16.2.2 Baseline Description

Baseline biomonitoring data available for RE-EWR 2 are summarised as follows:

Date	SASS5 Score	ASPT	No. of Taxa	Category (Dallas 2007)	MIRAI (%)	PES
09 - 08 - 07	28	3.1	9	E	36.3%	E

16.2.3 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration, and were selected as monitoring indicators for RE-EWR2. Although Baetidae, Caenidae and Dytiscidae were not recorded during the field survey in August 2007, they are expected in a wetland system such as this, even under degraded conditions.

Family	Flow				Substrate					Water Quality		
	Standing (<0.1 m/s)	Slow (0.1 - 0.3 m/s)	Mod (0.3 - 0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Veg	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7 - 10)	Low (SASS 4 - 6)
Baetidae (>2 spp)	●	●	⬤	⬤	●	●	⬤	●	●		10	
Caenidae (Squaregills)	●	⬤				●	⬤	●	●			6
Simuliidae (Blackflies)		●	⬤	⬤	⬤	⬤	⬤	⬤				5
Dytiscidae (Diving beetles)	⬤	●						⬤				5
Heptageniidae (Flathead mayflies)		●	●	●		●	⬤	●		13		
Hydropsychidae (>2 spp)			●	⬤	●	⬤	●			12		
Perlidae (Stoneflies)			●	⬤		●	⬤			12		
Psephenidae (Water pennies)			●	⬤		⬤	●				10	
Athericidae		●	⬤			●	⬤	●			10	
Leptophlebiidae (Prongills)	●	⬤	●		●	●	⬤	●	⬤		9	
Tricorythidae (Stout crawlers)			●	⬤	●	⬤	⬤	●			9	
Atyidae (Freshwater shrimps)		●						⬤			8	
Elmiidae (Riffle beetles)			●	⬤		⬤	●	●			8	
Lestidae	●	●						⬤			8	
Ancylidae	●	●	●	●	●	●	●	●				6
Hydropsychidae (2 spp)			●	⬤	●	⬤	●					5

● = Partial Preference ⬤ = Strong Preference

16.2.4 EcoSpecs and TPCs relating to the MIRAI data: PES

EcoSpecs and TPCs for the PES (D) at RE-EWR 2 are provided below:

ECOSPECS: Biota	TPCS
SASS5 Score between 90 and 130.	SASS5 Score < 100.
ASPT between 5.1 and 5.9.	ASPT < 5.3.
MIRAI Score between 42% and 57%.	MIRAI Score < 45%.
Baetidae > 2 spp.	Baetidae < 2 spp.
Caenidae present.	Caenidae absent from two or more consecutive surveys.
Simuliidae present.	Simuliidae absent on two or more consecutive surveys.
Dytiscidae present.	Dytiscidae absent from two or more consecutive surveys.

17 RECOMMENDATIONS

To date formal implementation of the monitoring step of the Reserve has not taken place (CJ Kleynhans, C Thirion, *pers. comm*). Furthermore, there has been minimal (only informally on the Palmiet River and on a private dam in the Western Cape) implementation (with reference to the supply of the flows and management of other drivers to achieve the required EC) of the Ecological Reserve. This is of major concern as all EWRs, EcoSpecs; TPCs etc. are hypotheses until tested. With increased development and pressure on the water resources in this country there are no structures in place to monitor the further deterioration of our rivers. All methods related to monitoring and the identification of EcoSpecs and TPCs therefore require testing and refinement.

The Upper Vaal River system has very high demands imposed on it by the irrigation sector, as well as industrial and domestic sectors and forms the backbone of the economic hub of South Africa.

The RHAM was developed during 2007 - 2009 and it is recommended that a RHAM survey is undertaken at sites where applicable. It is foreseen that due to the size and nature of the Vaal River, the RHAM for wadeable rivers might not be possible at all sites. The semi - wadeable (still to be tested) RHAM could be applicable. RHAM data may provide additional information on habitat suitability and the biota associated with this habitat.

No specific Ecological Reserve Monitoring has been initiated in this river system apart from the RHP monitoring conducted at EWR 9, 10, 11 and RE-EWR 2[3]. Immediate monitoring is necessary as the surveys undertaken during the Reserve study represent the baseline against which change is measured. These surveys were undertaken during 2007 and 2008 and it can already (pending changes in the catchments), not be applicable. The longer monitoring is delayed, the bigger the chance is that the baseline surveys will have to be repeated because of outdated data.

The main recommendation is that effective monitoring is started as soon as possible due to the economic importance of the Upper Vaal River and the presence of the Vredefort Dome Heritage site that falls within this study area below the Vaal River Barrage. The Upper Vaal River is exposed to regular water quality related impacts due to industrial activities that are not monitored as well as a failing municipal infrastructure that leads to pollution levels that lead to fish kills and the recreational activities being banned by the Department of Health, especially in the reaches below the Vaal Dam.

[3] According to Ms Hermien Roux and Mr Piet Muller, River Health Champions for the North West and Gauteng Provinces respectively (*Pers. comm.*, 2010).

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APPENDIX A:
ADDITIONAL MONITORING INFORMATION FOR FUTURE ECOLOGICAL WATER RESOURCE MONITORING

A1 GEOMORPHOLOGY

A1.1 MONITORING REQUIREMENTS

Monitoring frequency is recommended at 2 (for hydrology/EWR flow verification) to 5 (for bed material, cross - sections and aerial photography assessments) year intervals (Table A.1). However, in the event of a 1:10 - year or greater return period flood, it is recommended that the following dry season that the cross - section and bed material is resurveyed and fixed point photography is updated for the site. Table A.2 provides the flood magnitudes and frequencies at the EWR sites.

Table A1 Monitoring frequencies and interpretation

	Short - term monitoring (every second year)	Interpretation (every second year)	Long - term monitoring (every 5 to 10 years)	Interpretation (every 5 to 10 years)
HYDROLOGY	Update of the daily hydrological time series	Hydrological time series must be analysed to **verify that the requested flood flows have been provided at the sites.**	N/A	N/A
BED MATERIAL	N/A	N/A	Resurvey the bed material after 5 years along the cross - section/s (refer to the D_{16}, D_{50} and D_{84} percentile distribution of sediment in the relevant tables under each site discussion).	Analyse bed material distribution data and compare to previous and to TPCs provided for each site.
CHANNEL FORM	Fixed - point photography	Fixed point photography should be analysed for changes in channel geometry and hydraulic habitat (comparing the condition between the monitoring intervals). Reduction in critical habitats, and generally of channel width, is undesirable. Interpret in line with the site - specific guidelines provided in tables above.	Re - survey of fixed cross - sections Analysis of aerial photographs (if available)	Assess the resurveyed cross - sections and aerial photographs for any significant planform changes. Interpret these in terms of short - medium - changes in hydrology and land use Assess both **for signs of net aggradation** (increase in the bed level) **or net erosion/incision.** Many of the EWR sites have drastically narrowed channels, and further reductions in available habitat are undesirable.

All information must be interpreted in terms of medium to long - term trends and trajectories and the impact of flood(s).

After any 1:10 - year or greater return period flood:

- Re - survey cross - section.
- Re - survey bed material distribution, and
- Take fixed point photographs.

Table A2 Flood requirements for the REC for the 11 EWR sites

EWR site	Flood Parameter	Flood magnitude (m^3/s) and frequency of return interval			
EWR 1	Magnitude	15 - 35	50 - 120	200 - 340	420
	Frequency	2 per annum for 3 - 5 days	1:1 or 1:2	1:3 to 1:4	1:5
EWR 2	Magnitude		11 - 50	70 - 100	
	Frequency		1:1	1:2	
EWR 3	Magnitude	20	60		200
	Frequency	3:1	1:1		1:3
EWR 4	Magnitude			80	
	Frequency			1:2	
EWR 5	Magnitude	50 (daily average)			800 (daily average)
	Frequency	4 per year			1:3
EWR 6	Magnitude		10 - 15	20 - 50	>90
	Frequency		1:1	1:2	1:3 to 1:5
EWR 7	Magnitude	8 - 9			
	Frequency	>2:1			
EWR 8	Magnitude	65 - 90		100 - 150	>600
	Frequency	2:3		1:2	>1:10
EWR 9	Magnitude	1	2 - 4	13	>35
	Frequency	4	1:1	1:2	1:5
EWR 10	Magnitude	3.5 (daily average)	6 (daily average)	10 - 12 (daily average)	75 (daily average)
	Frequency	4	2	1	1:2
EWR 11	No floods set for this site. To maintain or improve the geomorphological condition at this site will require better management of the base flows (i.e. reduced base flows). Elevated base flows and increased flood peaks (from urbanization) have eroded any geomorphological cues.				

A2 FISH

A2.1 MONITORING REQUIREMENTS: EWR 1

EIS:	High
Red Data and other important species:	BKIM
Fish monitoring requirements:	
Frequency:	Every 3 years provided RHAM monitoring is in place and performed annually. Otherwise, perform monitoring every 2 years.
Season:	Dry season/low flows, preferably between September and December (once water warmed up and fish activity has increased).
Location:	At the EWR site, ensure adequate sampling of especially fast - shallow and slow shallows with vegetation. Conduct surveys at other sites in reach if possible.
Sampling method:	Perform at least electro - fishing for a minimum time of 60 minutes at EWR site.
Primary indicator species (EWR site)	LCAP < ASCL < BAEN < CGAR

1 Primary indicator species in order of intolerance to environmental changes (based on overall intolerance ratings) from most intolerant to more tolerant. Sampling should be focussed on ensuring adequate and consistent sampling of preferred habitats of especially these indicator species. **This is applicable to all sites.**

Monitoring frequency would be dependent on the sensitivity of the fish assemblage and the level of development of the system. The EIS should be consulted and the risk to the fish should be estimated to arrive at an estimation of vulnerability of the assemblage.

A2.2 MONITORING REQUIREMENTS: EWR 2

EIS:	Moderate
Red Data and other important species:	BKIM
Fish monitoring requirements:	
Frequency:	Every 3 years provided RHAM monitoring is in place and performed annually. Otherwise, perform monitoring every 2 years.
Season:	Dry season/low flows, preferably between September and December (once water warmed up and fish activity has increased).
Location:	At the EWR site, ensure adequate sampling of especially fast - shallow and slow shallows with vegetation. Conduct surveys at other sites in reach if possible.
Sampling method:	Perform at least electro - fishing for a minimum time of 60 minutes at EWR site.
Primary indicator species (EWR site)	BKIM < LCAP < BANO < ASCL < BAEN < BPAU < PPHI < CGAR

Monitoring frequency would be dependent on the sensitivity of the fish assemblage and the level of development of the system. The EIS should be consulted and the risk to the fish should be estimated to arrive at an estimation of vulnerability of the assemblage.

A2.3 MONITORING REQUIREMENTS: EWR 3

EIS:	Moderate
Red Data and other important species:	BKIM
Fish monitoring requirements:	
Frequency:	Every 3 years provided RHAM monitoring is in place and performed annually. Otherwise, perform monitoring every 2 years.
Season:	Dry season/low flows, preferably between September and December (once water warmed up and fish activity has increased).
Location:	At the EWR site, ensure adequate sampling of especially fast - shallow and slow shallows with vegetation. Conduct surveys at other sites in reach if possible.
Sampling method:	Perform at least electro - fishing for a minimum time of 60 minutes at EWR site.

Primary indicator species (EWR site)	LCAP < BANO < ASCL < BAEN < BPAU < PPHI < CGAR

Monitoring frequency would be dependant on the sensitivity of the fish assemblage and the level of development of the system. The EIS should be consulted and the risk to the fish should be estimated to arrive at an estimation of vulnerability of the assemblage.

A2.4 MONITORING REQUIREMENTS: EWR 4

EIS:	High
Red Data and other important species:	BKIM
Fish monitoring requirements:	
Frequency:	Every 3 years provided RHAM monitoring is in place and performed annually. Otherwise, perform monitoring every 2 years.
Season:	Dry season/low flows, preferably between September and December (once water warmed up and fish activity has increased).
Location:	At the EWR site, ensure adequate sampling of especially fast - shallow and slow shallows with vegetation. Conduct surveys at other sites in reach if possible.
Sampling method:	Perform at least electro - fishing for a minimum time of 60 minutes at EWR site.
Primary indicator species (EWR site)	LCAP < BAEN < BPAU < PPHI = TSPA

Monitoring frequency would be dependant on the sensitivity of the fish assemblage and the level of development of the system. The EIS should be consulted and the risk to the fish should be estimated to arrive at an estimation of vulnerability of the assemblage.

A2.5 MONITORING REQUIREMENTS: EWR 5

EIS:	High
Red Data and other important species:	BKIM
Fish monitoring requirements:	
Frequency:	Every 3 years provided RHAM monitoring is in place and performed annually. Otherwise, perform monitoring every 2 years.
Season:	Dry season/low flows, preferably between September and December (once water warmed up and fish activity has increased).
Location:	At the EWR site, ensure adequate sampling of especially fast - shallow and slow shallows with vegetation. Conduct surveys at other sites in reach if possible.
Sampling method:	Perform at least electro - fishing for a minimum time of 60 minutes at EWR site.
Primary indicator species (EWR site)	LCAP < BAEN < PPHI = TSPA

Monitoring frequency would be dependant on the sensitivity of the fish assemblage and the level of development of the system. The EIS should be consulted and the risk to the fish should be estimated to arrive at an estimation of vulnerability of the assemblage.

A2.6 MONITORING REQUIREMENTS: EWR 6

EIS:	Moderate
Red Data and other important species:	None
Fish monitoring requirements:	
Frequency:	Every 3 years provided RHAM monitoring is in place and performed annually. Otherwise, perform monitoring every 2 years.
Season:	Dry season/low flows, preferably between September and December (once water warmed up and fish activity has increased).
Location:	At the EWR site, ensure adequate sampling of especially fast - shallow and slow shallows with vegetation. Conduct surveys at other sites in reach if possible.
Sampling method:	Perform at least electro - fishing for a minimum time of 60 minutes at EWR site.
Primary indicator species (EWR site)	LCAP < BANO < LUMB

Monitoring frequency would be dependant on the sensitivity of the fish assemblage and the level of development of the system. The EIS should be consulted and the risk to the fish should be estimated to arrive at an estimation of vulnerability of the assemblage.

A2.7 MONITORING REQUIREMENTS: EWR 7

EIS:	High
Red Data and other important species:	None
Fish monitoring requirements:	
Frequency:	Every 3 years provided RHAM monitoring is in place and performed annually. Otherwise, perform monitoring every 2 years.
Season:	Dry season/low flows, preferably between September and December (once water warmed up and fish activity has increased).
Location:	At the EWR site, ensure adequate sampling of especially fast - shallow and slow shallows with vegetation. Conduct surveys at other sites in reach if possible.
Sampling method:	Perform at least electro - fishing for a minimum time of 60 minutes at EWR site.
Primary indicator species (EWR site)	BAEN

Monitoring frequency would be dependant on the sensitivity of the fish assemblage and the level of development of the system. The EIS should be consulted and the risk to the fish should be estimated to arrive at an estimation of vulnerability of the assemblage.

A2.8 MONITORING REQUIREMENTS: EWR 8

EIS:	Moderate
Red Data and other important species:	None
Fish monitoring requirements:	
Frequency:	Every 3 years provided RHAM monitoring is in place and performed annually. Otherwise, perform monitoring every 2 years.
Season:	Dry season/low flows, preferably between September and December (once water warmed up and fish activity has increased).
Location:	At the EWR site, ensure adequate sampling of especially fast - shallow and slow shallows with vegetation. Conduct surveys at other sites in reach if possible.
Sampling method:	Perform at least electro - fishing for a minimum time of 60 minutes at EWR site.
Primary indicator species (EWR site)	LCAP < BPAL < BANO < ASCL < BAEN < LUMB

Monitoring frequency would be dependant on the sensitivity of the fish assemblage and the level of development of the system. The EIS should be consulted and the risk to the fish should be estimated to arrive at an estimation of vulnerability of the assemblage.

A2.9 MONITORING REQUIREMENTS: EWR 9

EIS:	High
Red Data and other important species:	BKIM (possibility)
Fish monitoring requirements:	
Frequency:	Every 3 years provided RHAM monitoring is in place and performed annually. Otherwise, perform monitoring every 2 years.
Season:	Dry season/low flows, preferably between September and December (once water warmed up and fish activity has increased).
Location:	At the EWR site, ensure adequate sampling of especially fast - shallow and slow shallows with vegetation. Conduct surveys at other sites in reach if possible.
Sampling method:	Perform at least electro - fishing for a minimum time of 40 minutes at EWR site.
Primary indicator species (EWR site)	LCAP < BAEN < TSPA < CGAR

Monitoring frequency would be dependant on the sensitivity of the fish assemblage and the level of development of the system. The EIS should be consulted and the risk to the fish should be estimated to arrive at an estimation of vulnerability of the assemblage.

A2.10 MONITORING REQUIREMENTS: EWR 10

EIS:	Moderate
Red Data and other important species:	BKIM (possibly)
Fish monitoring requirements:	
Frequency:	Every 3 years provided RHAM monitoring is in place and performed annually. Otherwise, perform monitoring every 2 years.
Season:	Dry season/low flows, preferably between September and December (once water warmed up and fish activity has increased).
Location:	At the EWR site, ensure adequate sampling of especially fast - shallow and slow shallows with vegetation. Conduct surveys at other sites in reach if possible.
Sampling method:	Perform at least electro - fishing for a minimum time of 60 minutes at EWR site.
Primary indicator species (EWR site)	LCAP < BANO < BAEN < PPHI = TSPA < CGAR

Monitoring frequency would be dependant on the sensitivity of the fish assemblage and the level of development of the system. The EIS should be consulted and the risk to the fish should be estimated to arrive at an estimation of vulnerability of the assemblage.

A2.11 MONITORING REQUIREMENTS: EWR 11

EIS:	Low
Red Data and other important species:	None
Fish monitoring requirements:	
Frequency:	Every 3 years provided RHAM monitoring is in place and performed annually. Otherwise, perform monitoring every 2 years.
Season:	Dry season/low flows, preferably between September and December (once water warmed up and fish activity has increased).
Location:	At the EWR site, ensure adequate sampling of especially fast - shallow and slow shallows with vegetation. Conduct surveys at other sites in reach if possible.
Sampling method:	Perform at least electro - fishing for a minimum time of 50 minutes at EWR site.
Primary indicator species	BAEN < BPAU < PPHI < CGAR

(EWR site)	

Monitoring frequency would be dependant on the sensitivity of the fish assemblage and the level of development of the system. The EIS should be consulted and the risk to the fish should be estimated to arrive at an estimation of vulnerability of the assemblage.

A2.12 MONITORING REQUIREMENTS: RE-EWR 1

EIS:	Moderate
Red Data and other important species:	none
Fish monitoring requirements:	
Frequency:	Every 3 years provided RHAM monitoring is in place and performed annually. Otherwise, perform monitoring every 2 years.
Season:	Dry season/low flows, preferably between September and December (once water warmed up and fish activity has increased).
Location:	At the EWR site, ensure adequate sampling of especially fast - shallow and slow shallows with vegetation. Conduct surveys at other sites in reach if possible.
Sampling method:	Perform at least electro - fishing for a minimum time of 40 minutes at EWR site.
Primary indicator species (EWR site)	BANO < BAEN

Monitoring frequency would be dependant on the sensitivity of the fish assemblage and the level of development of the system. The EIS should be consulted and the risk to the fish should be estimated to arrive at an estimation of vulnerability of the assemblage.

A2.13 MONITORING REQUIREMENTS: RE-EWR 2

EIS:	Low
Red Data and other important species:	None (AJOH possible unique distribution in Vaal System)
Fish monitoring requirements:	
Frequency:	Every 3 years provided RHAM monitoring is in place and performed annually. Otherwise, perform monitoring every 2 years.
Season:	Dry season/low flows, preferably between September and December (once water warmed up and fish activity has increased).
Location:	At the EWR site, ensure adequate sampling of especially fast - shallow and slow shallows with vegetation. Conduct surveys at other sites in reach if possible.
Sampling method:	Perform at least electro - fishing for a minimum time of 30 minutes at EWR site.
Primary indicator species (EWR site)	BPAL < AJOH < BANO

Monitoring frequency would be dependant on the sensitivity of the fish assemblage and the level of development of the system. The EIS should be consulted and the risk to the fish should be estimated to arrive at an estimation of vulnerability of the assemblage.