Southern African Development Community

Water Sector Support Unit - Gaborone

European Development Fund

African Transboundary River Basin Support Programme

Case of the Orange – Senqu River in Botswana

Lesotho, Namibia and South Africa

Global Financial Commitment No. 9 ACP RPR 53

BASELINE MONITORING OF AQUATIC ECOSYSTEM HEALTH IN THE ORANGE-SENQU RIVER BASIN:

FINAL REPORT: PART 2 – MAIN REPORT

Report No. ORASECOM
March 2011

THIS REPORT HAS BEEN PREPARED BY:

Ms Colleen Todd
TECHNICAL PROJECT LEADER
PO Box 33319
Glenstantia
0010
Cell: 083 499 7668
E mail: colleenptodd@gmail.com

AND

Ms Shael Koekemoer
ADMINISTRATIVE PROJECT LEADER
PO Box 1100
Parys
9585
Cell: 084 240 5855
E mail: shaelk@eject.co.za

This report has been issued and amended as follows:

ISSUE	REVISION	DESCRIPTION	DATE	SIGNED
1		Draft for review	11 April 2011	

Project executed by:

CC 2004/094608/23
KAS
KOEKEMOER AQUATIC SERVICES

ACKNOWLEDGEMENTS

Contributors to the report:
Johan Koekemoer (Fish)
James McKenzie (Riparian vegetation)
Ntaki Senoge (Macroinvertebrates)

Marinda Avenant (Fish)
Marie Watson (Macroinvertebrates)
Marthie Kemp (Riparian vegetation)
Dr Jonathan Taylor (Diatoms)

Dr Johan Engelbrecht (Fish)
Colleen Todd (Macroinvertebrates)
Anton Linstrom (Riparian vegetation)
Shael Koekemoer (Diatoms)

Trainees:
Pashnee Pillay (Diatoms)
Ntaki Senoge (Macroinvertebrates)

Advisors:
Dr Rob Palmer
Ms Delana Louw
Mr Piet Muller

Compilation of report:
Shael Koekemoer
Colleen Todd

EXECUTIVE SUMMARY

BACKGROUND

Article 5.2.5 of the Orange-Senqu River Commission (ORASECOM) Agreement indicates that the Commission can advise its Contracting Parties (Botswana, Lesotho, Namibia and South Africa on 'standardised forms of collecting, processing and disseminating data or information with regard to all aspects of the River System". Article 7.12 requires the Parties to individually and jointly take all measures that are necessary to protect and preserve the River System from its sources and headwaters to its common terminus. To do this the Parties would need to be advised on the state of aquatic ecosystems throughout the basin. This gives ORASECOM the mandate and responsibility to develop an aquatic ecosystem health monitoring programme. Such a monitoring programme will also serve to satisfy some of the requirements of the Revised SADC Protocol on Shared Watercourses, to which all Parties are signatory (ORASECOM, 2009).

ORASECOM intends to monitor the Aquatic Ecosystem Health of the Orange-Senqu River through this programme. This monitoring programme provides for annual assessments of aquatic ecosystem health using the SASS5 system, as well as for 5 yearly more through assessments including a wider range of bio-monitoring protocols. The EU support to ORASECOM provided for the piloting of the first of these 5 yearly assessments. It was decided that this should form part of a Joint Basin Survey being undertaken by ORASECOM. This first assessment was intended to provide a snapshot of the health or condition of the entire basin – and would serve as a baseline against which ORASECOM could assess progress with measures to improve aquatic ecosystem health across the basin.

ORASECOM has proposed and agreed an Aquatic Ecosystem Health (AEH) monitoring programme (available at: http://www.orasecom.org/publications/eu+project+support.aspx?fileid=24). This programme suggested that annual monitoring of macroinvertebrates using the SASS5 system was supplemented by a 5 yearly intensive and detailed monitoring of aquatic ecosystem health using a wider range of biomonitoring protocols. This study was to be the first of these 5 yearly intensive monitoring programmes. It was, however, recognised in the original monitoring programme that this first survey would not only set a baseline condition for the system against which ORASECOM could monitor the impacts of any basin wide measures taken, but would also better define the most appropriate sampling sites based on local knowledge and site visits.

PURPOSE OF THIS ASSIGNMENT

The specific purpose of this assignment, which forms part of the greater EU project, is to undertake the first baseline monitoring of aquatic ecosystem health in the Orange-Senqu River System and to support the broader joint baseline survey. The focus of this specific assignment is to investigate the Aquatic Ecosystem Health of the Orange-Senqu River System and includes a detailed assessment of aquatic ecosystem health indicators, including the impacts affecting these systems.

SITE SELECTION

The Terms of Reference (ToR) initially provided fifty six (56) possible monitoring sites that could be included in a basin wide ecological monitoring programme. However, sampling of all the sites provided in the ToR could not be accommodated, due to budgetary constraints. For the purposes of this study, the study area was divided into four sub-areas which consisted of:

- Area 1: The Vaal River catchment – From the origins of the Vaal River to downstream of Douglas Weir in the Northern Cape Province. This includes the Upper, Middle and Lower Water management Areas (WMAs).
- Area 2: The Upper Orange catchment – The Upper Orange River and tributaries from the Lesotho border downstream to the confluence with the Vaal River below Douglas in the Northern Cape Province.
- Area 3: Lower Orange catchment – From the Vaal River confluence to the Orange River mouth.
- Area 4: Senqu River – From the origins of the Senqu to the South African border.

SITES SURVEYED

Based on the above information, the original 56 sites were re-examined and firstly either:

- Shifted as they were close to EFR sites.
- Shifted as they were close to Reserve sites.

After this elimination process sites were selected for surveying. This meant that the study could take advantage of data from previous studies.

Sixteen OSAEH sites were selected within these sub-areas, which represented the range of EcoRegions occurring in the study area; incorporated reference sites, potential monitoring sites as well as Ecological Reserve sites and allowed for the full suite of ecological components to be assessed i.e. fish, macroinvertebrates, diatoms, riparian vegetation, *in situ* water quality measurements and the determination of Instream Habitat Integrity. These sites also incorporated various impacts from the study area.

ASSESSMENT METHODS

The suite of assessment methods applied during the baseline survey were those incorporated within the South African River Health Programme (RHP), known as the EcoStatus methods and considered suitable for the Orange-Senqu River – and as outlined in ORASECOM Report no. 009/2009.

These response indices applied during this assignment and during the Reserve studies were:

- Macroinvertebrates – MIRAI (Macroinvertebrate Response Assessment Index);
- Fish – FRAI (Fish Response Assessment Index);
- Riparian vegetation – VEGRAI (Riparian Vegetation Response Assessment Index, Level 3 or 4);
- Habitat Integrity – IHI (Index of Habitat Integrity) and
- Diatoms as outlined in Taylor *et al*. (2007).

PURPOSE OF THIS REPORT

This report provides the detailed results of the ecosystem health baseline monitoring and includes an analysis of the raw data, as well as some indication of the overall status of the site when compared to a reference condition. A qualitative assessment of the macroinvertebrate data made available by the Lesotho Highlands Development Authority for the Senqu River as well as macroinvertebrate data from a Fish River study undertaken during 2009-2010 by Nepid Consultants is provided.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

ASPT	Average Score Per Taxon
CMA	Catchment Management Agency
DO	Dissolved Oxygen
EFR	Environmental Flow Requirement
FD	Fast Deep fish habitat
FRAI	Fish Response Assessment Index
FS	Fast Shallow fish habitat
Geom	Geomorphology
GSM	Gravel, sand, mud habitat
GWS	Government Water Scheme
IHI	Index of Habitat Integrity
IIHI	Instream Index of Habitat Integrity
Inverts	Macroinvertebrates
LB	Left Bank
LHWP	Lesotho Highlands Water Project
MIRAI	Macro Invertebrate Response Assessment Index
MRU	Management Resource Unit
MV	Marginal Vegetation
NF	Non Flow related
NWRS	National Water Resources Strategy
ORASECOM	Orange-Senqu River Commision
OSAEH	Orange-Senqu Aquatic Ecosystem Health
PES	Present Ecological State
RAU	Resource Assessment Unit
RB	Right Bank
RHP	River Health Programme
RIHI	Riparian Index of Habitat Integrity
Rip Veg	Riparian vegetation
RU	Resource Unit
SASS5	South African Scoring System version 5
SD	Slow Deep fish habitat
SIC	Stones-in-current habitat
SOOC	Stones-out-of-current habitat
SPI	Specific Pollution Index
SS	Slow Shallow fish habitat
TDS	Total Dissolved Salts
ToR	Terms of Reference
TPC	Threshold of Potential Concern
VEGRAI	Vegetation Response Assessment Index
WMA	Water Management Area
WWTW	Waste Water Treatment Works

1 INTRODUCTION

1.1 BACKGROUND

Article 5.2.5 of the Orange-Senqu River Commission (ORASECOM) Agreement indicates that the Commission can advise its Contracting Parties (Botswana, Lesotho, Namibia and South Africa on 'standardised forms of collecting, processing and disseminating data or information with regard to all aspects of the River System". Article 7.12 requires the Parties to individually and jointly take all measures that are necessary to protect and preserve the River System from its sources and headwaters to its common terminus. To do this the Parties would need to be advised on the state of aquatic ecosystems throughout the basin. This gives ORASECOM the mandate and responsibility to develop an aquatic ecosystem health monitoring programme. Such a monitoring programme will also serve to satisfy some of the requirements of the Revised SADC Protocol on Shared Watercourses, to which all Parties are signatory (ORASECOM, 2009).

ORASECOM intends to monitor the Aquatic Ecosystem Health of the Orange-Senqu River through this programme. This monitoring programme provides for annual assessments of aquatic ecosystem health using the SASS5 system, as well as for 5 yearly more through assessments including a wider range of bio-monitoring protocols. The EU support to ORASECOM provided for the piloting of the first of these 5 yearly assessments. It was decided that this should form part of a Joint Basin Survey being undertaken by ORASECOM. This first assessment was intended to provide a snapshot of the health or condition of the entire basin – and would serve as a baseline against which ORASECOM could assess progress with measures to improve aquatic ecosystem health across the basin.

1.2 PURPOSE OF THIS ASSIGNMENT

The specific purpose of this assignment, which forms part of the greater EU project, is to undertake the first baseline monitoring of aquatic ecosystem health in the Orange-Senqu River System and to support the broader joint baseline survey. The focus of this specific assignment is to investigate the Aquatic Ecosystem Health of the Orange-Senqu River System and includes a detailed assessment of aquatic ecosystem health indicators, including the impacts affecting these systems.

1.2.1 Outcomes of this assignment

According to the Terms of Reference (ToR) the results of this assignment include:

1 **Report 1: Detailed sampling programme.** This report was finalised during October 2009 and outlines the sites selected for the purpose of this assignment, and provides detailed information on the sampling protocols that would be applied at each site. A detailed sampling programme was also provided.

2 **Presentation of sampling programme.** The sampling programme was presented at the briefing session held at St. Georges Hotel, Irene on 22 September 2010.

3 **Undertaking of monitoring according to monitoring programme.** Field trips were undertaken during 25 – 29 October 2010 and 1 – 6 November 2010, and March 2011.

4 **Final report:** The final report is provided in two parts.

- The first part of the report, also referred to as the summary report provides a summary of the results of the aquatic ecological baseline survey undertaken at the monitoring sites outlined in Section 2.2. Part 1 also includes the summarised results of the Ecological Water Requirement (EWR sites) of the Reserve studies undertaken during 2007 – 2010 by other agencies – including the environmental flows work undertake as part of the GIZ/DFID support to ORASECOM.

- The second part of the report (this report), also referred to the main report includes the detailed results of the ecosystem health baseline monitoring and includes an analysis of the raw data, as well as some indication of the overall status of the site when compared to a reference condition.
- The suite of EcoStatus models and component assessment models applied to this study will be provided in electronic format.

1.3 PURPOSE OF THIS REPORT

This report serves to summarise the results of the Orange-Senqu Aquatic Ecosystem Health (OSAEH) monitoring undertaken during October – November 2010 and March 2011 at sixteen selected sites.

1.4 REPORT OUTLINE

The outline of the report is provided below.

1.4.1 Chapter 1: Introduction

This chapter.

1.4.2 Chapter 2: Assessment Methods

This section provides an overview of the methods applied during the site assessment for the different components.

1.4.3 Chapter 3 – 18: Assessment of OSAEH sites

Detailed results of the ecosystem health baseline monitoring is provided and includes an analysis of the raw data, and gives an indication of the overall status of the site when compared to a reference condition.

1.4.4 Chapter 19: Senqu River: Qualitative assessment of SASS 5 data

A qualitative analysis of the macroinvertebrate data as provided by LDHA is provided.

1.4.5 Chapter 20: Fish River: Qualitative assessment of SASS 5 data

A qualitative analysis of the macroinvertebrate data, collected during 2009 – 2010 is provided.

1.4.6 Chapter 21: Recommendations

2 ASSESSMENT METHODS

2.1 BACKGROUND

The suite of assessment methods proposed are those incorporated within the national River Health Programme (RHP), known as the EcoStatus methods. These methods are considered suitable for the Orange-Senqu River baseline survey.

Biotic indices are numerical indices that use a component/s of the biota to give an indication of the biological integrity of a site. For example, the macroinvertebrate rapid bioassessment method, SASS (South African Scoring System) was developed to assess macroinvertebrates in rivers and streams and to provide information regarding the biotic integrity of the system. These indices summarize biological data into one or more metric, for example the MIRAI, FRAI etc.

The response indices are those which respond to the abiotic conditions created by the driver indices. These response indices are:

- Macroinvertebrates – MIRAI (Macroinvertebrate Response Assessment Index);
- Fish – FRAI (Fish Response Assessment Index);
- Riparian vegetation – VEGRAI (Riparian Vegetation Response Assessment Index); and
- Habitat Integrity – IHI (Index of Habitat Integrity).
- Diatoms.

The models indicated above are called EcoStatus models and are used in the EcoClassification process. Each model characterises the biological component being assessed into an Ecological Category. This is expressed as a category in a continuum from A to F, where A represents conditions close to natural and F being critically modified condition (Table 2.1).

This project will follow the EcoClassification process, mostly as far as the biological responses are concerned. The drivers are very broadly characterized as they form a cause and effect relationship with the biological responses. The EcoClassification process determines causes and sources of biophysical attribute deviation from the reference condition.

Table 2.1 Generic ecological categories for EcoStatus components (Kleynhans and Louw (2007)

Ecological Category	Description	Score (% of Total)
A	Unmodified, natural.	90-100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-89
C	Moderately modified. Loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39
F	Critically/extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.	0-19

2.2 BIOLOGICAL INDICES

The indices that will be used are outlined below in Table 2.2 (Kleynhans and Louw, 2007).

Table 2.3 Indices applied during RHP monitoring

Indicator	Index applied for obtaining results	Index applied for assessing results
Fish	Fish Assemblage Integrity Index (FAII)	Fish Response Assessment Index (FRAI) Kleynhans (2007)
Macroinvertebrates	South African Scoring System version 5 (SASS5)	Macroinvertebrate Response Assessment Index (MIRAI) Thirion (2007)
Riparian vegetation	Riparian Vegetation Index (RVI)	Vegetation Response Assessment Index (VEGRAI) Kleynhans *et al*. (2007a)
Habitat Integrity	Index of Habitat Integrity (IHI) which assesses the effect of disturbances in instream and riparian zone habitat. Kleynhans *et al*. (2009)	

2.2.1 Macroinvertebrate index (SASS and MIRAI)

SASS is a rapid, biomonitoring tool that was developed for lotic (flowing water) systems only. The method assesses macroinvertebrate communities occupying different instream habitats and uses pre-determined sensitivity weightings assigned per taxon. Macroinvertebrates are identified mostly to family taxonomic level. The method gives an indication of water quality impairment and overall river integrity/health. Detail on the method can be obtained from Dickens and Graham (2002).

The MIRAI (Macroinvertebrate Response Assessment Index) was developed for use by experienced, invertebrate, river ecologists (Thirion, 2007). This assessment index provides a habitat-based cause-and-effect foundation to interpret the deviation of the macroinvertebrate assemblage from reference condition (Thirion, 2007). SASS data only or more detailed data is suitable for use in the MIRAI. The MIRAI generates an Ecological Category for macroinvertebrates by integrating the ecological requirements of an assemblage and relating this to modified flow, instream habitat and water quality conditions.

2.2.2 Fish index (FRAI)

The FRAI (Fish Response Assessment Index) was developed to provide a habitat-based, cause-and-effect index to interpret the deviation of a fish assemblage from the reference condition (DWAF, 2008a).

The FRAI index uses the following (DWAF, 2008a):

- Environmental intolerances and preferences of the reference fish assemblage; and
- Response of the constituent species to certain environmental determinants or drivers.

2.2.3 Riparian vegetation index (VEGRAI)

The VEGRAI is an impact-based, rapid, cause-and-effect assessment index, detecting changes in vegetation condition. The model compares the present day riparian vegetation condition to that in its reference state.

2.2.4 Index of Habitat Integrity (IHI)

This index measures habitat integrity of a river and refers to the maintenance of a balanced composition of habitat and physico-chemical characteristics within a temporal and spatial scale when compared to that of the reference habitats within the region (Kleynhans *et al.,* 2009).

Collection of land-use information and anthropogenic impacts was done prior to the field assessment and this information pertained to modification of instream habitat and riparian zone modification.

The IHI component was assessed on site under the leadership of one experienced specialist that was responsible for the population of the IHI model.

2.2.5 Diatoms

Diatoms are ecologically important because of their role as primary producers, which form the base of the aquatic food web, and because they usually account for the highest number of species among the primary producers in aquatic systems (Leira and Sabater, 2005). Diatoms are photosynthetic unicellular organisms and are found in almost all aquatic and semi-aquatic habitats. They have been shown to be reliable indicators of specific water quality problems, such as organic pollution, eutrophication, acidification and metal pollution (Tilman *et al*., 1982; Dixit *et al*., 1992; Cattaneo *et al.,* 2004), as well as for general water quality (AFNOR, 2000).

Sampling methods followed Taylor *et al.* (2005a, b; 2007a). These methods were designed and refined as part of the Diatom Assessment Protocol, a Water Research Commission initiative. Taylor *et al.* (2007a) based the method manual on several key documents including CEN (2003), and DARES (2004).

Preparation of diatom slides followed the Hot HCl and KMnO4 method as outlined in Taylor *et al.* (2007a). A Zeiss microscope with phase contrast optics (1000x) was used to identify diatom valves on slides. The aim of the data analysis was to identify and count diatom valves to produce semi-quantitative data from which ecological conclusions can be drawn (Taylor *et al.* 2007a). Schoeman (1973) and Battarbee (1986) concluded that a count of 400 valves per slide is satisfactory for the calculation of relative abundance of diatom species and this range is supported by Prygiel *et al.* (2002), as cited by Taylor *et al.* (2007a). Therefore a count of 400 valves per sample or more was counted and the nomenclature followed Krammer and Lange-Bertalot (1986-91). Diatom index values were calculated in the database programme OMNIDIA for epilithon data (Lecointe *et al.* 1993).

In general, each diatom species used in the calculation of the index is assigned two values; the first value reflects the tolerance or affinity of the particular diatom species to a certain water quality (good or bad) while the second value indicates how strong (or weak) the relationship is. These values are then weighted by the abundance of the particular diatom species in the sample. The diatom index used at present in this study is the Specific Pollution sensitivity Index (SPI; Coste in CEMAGREF 1982), one of the most extensively tested indices in Europe. Class limit boundaries for the SPI, as set by Prygiel and Coste (2000) (Table 2.2), were adapted for the determination of the Present Ecological State of riverine aquatic ecosystems and is presented in Table 2.3.

Table 2.2 Interpretation of the Specific Pollution sensitivity Index (SPI) scores

SPI Score	Class
>17	High quality
13 to 17	Good quality
9 to 13	Moderate quality
5 to 9	Poor quality
<5	Bad quality

Table 2.3 Adjusted class limit boundaries for the SPI index for the determination of the Present Ecological State

Index score (SPI score)	Class	Ecological Category
>17.3	High quality	A
16.8 - 17.2		A/B
13.3 - 16.7	Good quality	B
12.9 - 13.2		B/C
9.2 - 12.8	Moderate quality	C
8.9 - 9.1		C/D
5.3 - 8.8	Poor quality	D
4.8 - 5.2		D/E
<4.8	Bad quality	E

2.3 SITES SURVEYED

Sixteen OSAEH sites were selected which represented the range of EcoRegions occurring in the study area; incorporated reference sites, potential monitoring sites as well as Ecological Reserve sites and allowed for the full suite of ecological components to be assessed i.e. fish, macroinvertebrates, diatoms, riparian vegetation, *in situ* water quality measurements and the determination of Instream Habitat Integrity. These sites also incorporated various impacts from the study area.

Table 2.4 provides a list of the sixteen OSAEH sites that were sampled during October – November 2010 and March 2011

Table 2.4 OSAEH sites assessed in the Orange-Senqu River Basin

Site	Monitoring type	Eco-Region	Major River	Latitude	Longitude	Site code
OSAEH_11_1[1]	Monitoring Site P	11	Vaal	-27.51729	26.21604	C2VAALBLOEM
OSAEH_11_3	Monitoring Site C	11	Vaal/Mooi	-26.68283	27.09856	C2MOOIMEULS
OSAEH_11_4	Monitoring Site C	11	Vaal/Skoonspruit	-26.93333	26.66527	C2SKOOURANI
OSAEH_11_6	Monitoring Site P	11	Vaal/Renoster	-27.05286	27.00991	C7RENOR501B
OSAEH_11_8	Ecological Reserve Site	11	Vaal/Blesbokspruit	-26.475	28.43194	C2BLESMARAI
OSAEH_11_13[2]	Reference Site	11	Vaal/Kromellenboog	-26.8003	27.58428	C2KROMAVAAL
OSAEH_11_14	Monitoring Site C	11	Vaal/Suikerbosrand	-26.68122	28.05011	C2SUIKBADFO
OSAEH_11_18	Monitoring Site P	11	Riet/Modder	-29.16111	26.57194	C5MODDSANNA
OSAEH_11_21	Reference Site	11	Modder/Karonnaspruit	-29.08107	26.62615	C5KORAMOCKE
OSAEH_26_1	Ecological Reserve Site	26	Vaal	-29.00083	23.80646	C9VAALDOUGL
OSAEH_26_10	Ecological Reserve Site	26	Riet	-29.57528	25.70805	C5RIETIFR03
OSAEH_26_17	Monitoring Site P	26	Orange	-28.43861	21.40583	D7ORANGIFKL
OSAEH_28_5	Ecological Reserve Site	28	Orange	-28.04051	17.06967	D8ORANBOOMR
OSAEH_29_2[3]	Monitoring Site P	29	Vaal	-28.11097	24.80193	C9VAALWARRE
OSAEH_29_4	Monitoring Site C	29	Vaal	-28.72533	24.07293	C9VAALSCHMI
OSAEH_29_5	Ecological Reserve Site	29	Riet	-29.02805	24.5125	C5RIETIFR01

1 OSAEH 11.1 was relocated to Wolwespruit Nature Reserve, as Google Imagery indicated very little instream habitat. Based on information provided by the Reserve manager, Mr Mmole Teme, riffle areas were present in the Reserve and provided adequate instream habitat for the full suite of biotic component sampling. Based on land use this site could provide different/unique habitat types, and direct landuse impacts would be less than outside the reserve which is agriculturally dominated.
2 A new site was selected to accommodate the PR event. The site is located in the Vaal River at Parys.
3 OSAEH 29.2 was substituted by EWR 16 which was assessed as part of the Middle Vaal Reserve Study during 2007-2008. EWR 16 is situated below Bloemhof Dam and is the border between two EcoRegions and 120 km upstream of OSAEH 29.2. This site was selected as there was adequate instream habitat and access.

3 EWR 10: SUIKERBOS DS (SUIKERBOSRAND RIVER)

EWR 10 occurs downstream of the Blesbokspruit River which is heavily impacted an in close proximity to OSAEH 11.14 which is downstream of EWR 10. During the Reserve assessment (DWA, 2010) there was very low confidence in the hydrology and after personal communication with Ms Delana Louw it was decided to include EWR 10 in the current study and instead of assessing OSAEH 11.14, EWR 10 was assessed in March 2011. The EWR study allowed for good data availability and understanding of the site and the main aim of the March 2011 sampling was to determine if the PES baseline could have changed since 2007/8 as there was uncertainties regarding the hydrology during the Reserve study.

During March 2011 fish and macroinvertebrates along with diatoms were sampled. After consultation with Mr James Mckenzie, it was decided not to reassess riparian vegetation and the IHI as the condition of these components had not changed from the Reserve assessment. Mr Piet Muller (previously from Gauteng Provincial Government: GDACE and Gauteng River Health Champion) attended the site visit and provided valuable information regarding current land use and future management strategies of the area.

3.1 SITE DESCRIPTION

Location	EWR 10	**Altitude**	1453 m
Longitude	28.16798	**Latitude**	-26.68137
EcoRegion	Highveld/Southern Central Kalahari 11.01	**Quaternary catchment**	C21G
Water Management Area	Upper Vaal	**Geomorphological zone**	Lowland

EWR 10 is situated in the Suikerbosrand River downstream of the Blesbokspruit River confluence and upstream impacts include gold mining. Surrounding land use consisted of maize and cattle farming with natural field for cattle and game grazing and weirs occur up and down stream of the site. Fast (strong) flow was observed during the survey, and flow levels were recently very high due to floods in the region (approx. 3 – 4 m higher than pictured below). Instream substrate consisted of predominantly rocks, cobbles and boulders (10% consisted of sand). Sand and sedge on margins were prevalent with instream rocky habitat. Marginal aquatic vegetation was abundant (*Cyperus* sp. and *Juncus* sp. – sedges) and siltation and benthic growth was moderate (but rocks were still slippery) (Figure 3.1). Rocks were 5 - 10% embedded. The river banks in this reach are impacted by mining activities, agriculture, and developments) but the recent floods carried sand deposits downstream and to site (*pers. comm*. Mr. P. Muller) (Figure 3.2).

Figure 3.1 Rapid, riffle, run habitat running into pool habitat (note marginal vegetation and some instream sedges)

Figure 3.2 Alluvial sand deposits on right hand bank

3.2 BIOTIC SAMPLING

3.2.1 Fish

The fish sampling was conducted at the site during March 2011. A river stretch of approximately a 100 m long, consisting of a long riffle type habitat below rapids at an island in the stream. At the time of sampling the habitat was predominantly fast deep. Four depth classes were sampled for 60 minutes in this stretch of river that was flowing strong at the time of sampling. Sampling and data analysis was followed according to Kleynhans (2007). A summary of the site conditions during sampling is provided below. Abundance of habitat was rated as:

- 0 = absent
- 1 = rare
- 2 = sparse
- 3 = moderate

- 4 = abundant
- 5 = very abundant

Fish velocity-depth classes and cover present at the site

SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
3	3	5	5
Overhanging vegetation			
3	4	2	3
Undercut banks and root wads			
4	2	2	2
Substrate			
2	4	5	5
Aquatic macrophytes			
3	3	2	3
Water Column			
5	5	5	5

Habitats sampled and effort

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Electro shocker (min)	10 min	20 min	10 min	20 min

3.1 DATA AVAILABILITY

Detailed information regarding available data is provided in Table 3.1.

Table 3.1 EWR 10: Summary of data availability

Comp	Data availability	Conf
Fish	Site visit and fish sampling during April 2008 and march 2011. **Rivers data base** (2007): *Database on fish distribution in South African Rivers*. **Scott *et al.*** (2006): *Atlas of Southern African Freshwater Fishes*. South African Institute of Aquatic Biodiversity (SAIAB) data base (2006). **Kleynhans, C.J., Louw, M.D & Moolman, J**. 2007b. Module D (Volume 2): Reference Frequency of Occurrence of Fish Species in South Africa: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry Report. WRC Report No. TT330/08. Water Research Commission, Pretoria, South Africa. **Kotze and Niehaus** (2000 – 2004): Biomonitoring program for Rand Water. **Kotze (2002)**: Ecological integrity of Klip & Suikerbosrand River.	4
Inverts	Three SASS5 surveys undertaken during Apr 08, Sep 07 and Mar 2011. Report information used: Ecological reports and specialist assessments of the Reserve study. **Chutter** (1967): *Hydro biological Studies of the Vaal River*.	4

3.2 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 3.2. Additional information on fish, and macroinvertebrate reference conditions are also provided.

Table 3.2 EWR 10: Reference conditions

Comp	Reference conditions	Conf
Fish	Reference conditions for the site were based on the National River Health Programme (NRHP) site, C2SUIK-BADFO. See Table 3.3 for a list of the reference fish species.	4
Inverts	Reference conditions are based on professional judgment and Chutter (1967) from Sites 7, 15, 16 and 17 (Chutter 1967: Table 11). The reference SASS5 score is 182 and the ASPT is 6.1.	4

3.2.1 Fish

Reference conditions broadly refer to "expectations on the state of aquatic biological communities in the absence of human disturbance and pollution". In the context of this report, it refers specifically to the fish species present in a particular river reach and their frequency of occurrence under reference habitat conditions. Reference conditions for the site were largely based on the NRHP site, C2SUIK-BADFO (Kleynhans *et al.,* 2007b).

Ten indigenous fish species are expected under reference conditions and are listed in Table 3.3.

Table 3.3 EWR 10: Reference fish species

Expected Reference and Habitat derived FROC of fish at EWR 10 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Austroglanis sclateri	Rock catfish	ASCL	4	1
Labeobarbus aeneus	Smallmouth yellowfish	BAEN	4	4
Barbus anoplus	Chubbyhead barb	BANO	4	2
Barbus pallidus	Goldie barb	BPAL	3	0
Labeobarbus kimberleyensis	Largemouth yellowfish	BKIM	3	1
Clarias gariepinus	Sharptooth catfish	CGAR	4	3
Labeo capensis	Orange River labeo	LCAP	4	4
Labeo umbratus	Moggel	LUMB	3	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	4
Tilapia sparrmanii	Banded tilapia	TSPA	4	4
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%) 3 = present at about >25 - 50 % of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)				
ALIEN AND INVASIVE SPECIES				
Cyprinus carpio	Common Carp	CCAR		
Gambusia affinus	Mosquito fish	GAFF		
Micropterus salmoides	Largemouth bass	MSAL		

3.2.2 Macroinvertebrates

Macroinvertebrate taxa expected under reference conditions include:
Ancylidae, Hydropsychidae > 2 sp, Heptageniidae, Elmidae/Dryopidae, Leptophlebiidae, Turbellaria, Hydraenidae, Coenagrionidae, Hydroptilidae, Ceratopogonidae, Sphaeriidae, Baetidae > 2 sp, Tricorythidae, Simuliidae, Potamonautidae, Ecnomidae, Atyidae, Gomphidae, Corixidae, Chironomidae, Corbiculidae, Oligochaeta, Caenidae, Aeshnidae, Belostomatidae, Veliidae/M...veliidae, Dytiscidae/Noteridae, Gyrinidae, Porifera and Hirudinea

3.3 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information provided with this report.

3.3.1 Index of Habitat Integrity (IIHI: C EC, 64%; RIHI: C EC, 77%)

Based on the DWA (2010) the major impact on instream habitat integrity is anthropogenic activities (e.g. mines and Sappi) and urban stormwater runoff that has caused increased runoff, water quality problems and scouring. Riparian integrity is mainly impacted by increased floods due to anthropogenic activities and farming as cattle trampling is evident and impacting on bank structure.

3.3.2 Diatoms (C EC)

The Reserve results were based on four diatom samples taken at this site (August and December 2007 and January and April 2008). All four samples indicated that pollution levels were extreme and that the poor water quality of the Blesbokspruit River impacted heavily on this site. Nutrient loading, organic pollution and salinity were a major concern and mine water decant and industrial effluent impacted at critical levels. Toxics, oxygen and temperature were also variables of concern at this site. Due to the continual elevated flows the impacts were diluted constantly. The biological water quality was assessed as a C/D EC due to the dilution effect.

The March 2011 sample indicated that conditions were similar to the previous Reserve results. The flows at the time of sampling were elevated and this might have had a dilution effect on prevailing conditions. The diatoms indicated a EC of a C.

3.3.3 Fish (C EC, 62.8%)

According to Kotze (DWA, 2010) the fish PES was a C/D (**FRAI = 61%).** During the March 2011 survey, the PES was found to be slightly higher resulting in a C EC, most probably due to high flow at the time of the survey, resulting in more available habitat and flushing of sediment. This correlates with the previous findings of Kotze (DWA, 2010). The conditions at the site do not seem to have changed, and therefore the baseline PES has not changed since 2007/08.

Most of the expected fish species are still present within this reach. It is expected that *B. pallidus* has been lost from this reach as a result of the deteriorated water quality and increased flows (loss of slow habitats). According to Kotze (DWA, 2010) the loss of slow habitats also influenced other species with a preference for this habitat such as *B. anoplus*, *L. umbratus* and possibly also *C. gariepinus*. *C. gariepinus* was found in SS, FS, and FD habitat at the site. It is a highly adaptive and opportunistic species. Only juveniles were sampled, and therefore, the FROC of this species was not increased from Kotze (DWA, 2010). *A. sclateri* and *B. kimberleyensis* assemblages have been altered due to substrate deterioration (sediment and algae) as well as water quality. According to Kotze (DWA, 2010) another prominent reduction in FROC is evident in the small species (*B. anoplus*, *B. pallidus* and *P. philander*) most probably due to the presence of the predatory alien *M. salmoides*. *P. philander* was sampled as expected in its expected habitat during the March 2011 survey (the FROC, however, remains the same as noted by Kotze (DWA, 2010).

Other alien species *G. affinis* and *C. carpio* are also expected to have an impact on the indigenous species, especially regarding breeding (egg and larvae disturbance and predation). Migration barriers in the form of weirs also affect the fish assemblages of this reach to some extent.

3.3.4 Macroinvertebrates (C EC, 70.8%)

For list of families present in the sample please refer to the MIRAI.

SASS results:

Sep 07: SASS5 score: 64	No of Taxa: 13	ASPT: 4.9
Apr 08: SASS5 score: 85	No of Taxa: 15	ASPT: 5.7
Mar 11: SASS5 score: 115	No of Taxa: 21	ASPT: 5.5

The SASS score in March 2011 (115) is higher than the previous two sampling events in 2007 (64) and 2008 (85). However, the total score is still much lower than expected (182), although it is definitely an improvement from the previous two sampling events. The ASPT is, however, lower than the 2008 sampling event (5.7), with a score of 5.5 obtained in March 2011. The EC is currently a C (70.8%) as opposed to that of a C/D in 2008 (59.3%). The driver metric that is

impacted the most is that of water quality (34% difference from natural conditions). Taxa missing that have a high requirement for fast flowing water and also a high requirement for unmodified physic-chemical conditions include Perlidae. Taxa that were missing that have a moderate requirement for unmodified physic-chemical conditions include Tricorythidae, Aeshnidae and Hydraenidae. Taxa that were observed but not expected include Belostomatidae, Gerridae, Notonectidae and Pleidae.

Based on the above information, it does not seem as if the PES baseline has changed since 2007/08.

3.3.5 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 3.4.

Table 3.4 EWR 10: Causes and sources

	PES	Causes	Sources	F/NF
Fish	C	Altered habitat composition (slow habitats transformed to fast habitats).	Increased flows / altered hydrological regime.	F
		Decreased overhanging vegetation as cover for fish.	Grazing, agriculture and water level fluctuations.	NF
		Increased sedimentation results in deterioration of substrate as habitat (clogging of interstitial spaces, loss of important spawning habitats and feeding substrate, etc.).	Bank erosion and vegetation removal (grazing) contribute to increased sedimentation. Upstream mining resulting in sedimentation.	
		Decreased species diversity and abundance (especially small species).	Presence of aggressive alien predatory species *M. salmoides* and *G. affinis* naturally spreading and introduced for/as aquarium species, mosquito control, and recreation / angling.	
		Decreased bottom substrate quality.	Impact of bottom feeding alien *C. carpio* and siltation due to mining, as well as benthic growth due to nutrient enrichment due to waste water treatment works.	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Dams and various weirs. Also farm dams in tributaries reduce refuge areas.	
Inverts	C	Water quality problems, particularly elevated salinity and bacteria.	Industries (Mines, Sappi) and urban storm water.	NF
		Benthic algae.	Elevated nutrients.	
		Increased sedimentation.	Urbanization, agriculture, mining.	
		Constantly elevated base flows.	Decanting mines, sewage treatment works and seepage from urban development.	F

3.4 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 3.5.

Table 3.5 EWR 10: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Fish	C	Stable			t is estimated that the fish species have been exposed to the current impacts over a long period, and that they have adapted to the prevailing conditions. The findings of the recent March 24th 2011 survey correlate with the PES and PES trend as set by Kotze (DWA, 2010)).	3
Inverts	C	Stable			The macroinvertebrates have already reacted to the current conditions. findings of the recent March 24th 2011 survey correlate with the PES and PES trend as set by Palmer (DWA, 2010)).	3

3.5 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 3.6. The Instream EC is a C (66.8%).

Table 3.6 EWR 10: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	2.5	70		
2.What is the natural diversity of **fish** species with a preference for different cover types	4	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3.5	90		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2	70		
FISH ECOLOGICAL CATEGORY	12	330	**62.8**	**C**
MACROINVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	3	90		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	3	80		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	4	100		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**10**	270	**70.8**	**C**
INSTREAM ECOLOGICAL CATEGORY (Excl confidence)		600	**67.5**	**C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	3.5	0.50	31.40	
Confidence rating for **macroinvertebrate** information	3.5	0.50	35.40	
	7	1.00	66.80	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**C**	

To determine the EcoStatus, the Vegetation Response Assessment Index (VEGRAI) EC and confidence is included in the EcoStatus assessment index (Table 3.7). The EcoStatus EC is a C.

Table 3.7 EWR 10: Instream EC

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**62.4**	**C**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	3.5	0.51	34.38
Confidence rating for riparian vegetation zone information	3.3	0.49	30.28
	6.8	1.00	64.66
ECOSTATUS	**EC**		**C**

3.6 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised in Table 3.8.

Table 3.8 EWR 10: EcoClassification results

2007-2008			2010		
Driver Components	**PES**	**Trend**	**Driver Components**	**PES**	**Trend**
GEOMORPHOLOGY	C	Negative (C)	IHI: INSTREAM	C	
WATER QUALITY	D/E	Negative	IHI: RIPARIAN	C	
DIATOMS	C/D		DIATOMS (WQ)	C	
Response Components	**PES**	**Trend**	**Response Components**	**PES**	**Trend**
FISH	C/D	Stable	FISH	C	Stable
MACRO INVERTEBRATES	C/D	Stable	MACRO INVERTEBRATES	C	Stable
INSTREAM	C/D		INSTREAM	C	
RIPARIAN VEGETATION	C	Negative	RIPARIAN VEGETATION	C	Negative
ECOSTATUS	C/D		ECOSTATUS	C	

4 EWR 11: BLESBOKSPRUIT (BLESBOKSPRUIT RIVER)

During the Reserve assessment (DWA, 2010) there was very low confidence in the hydrology and after personal communication with Ms Delana Louw it was decided to include EWR 11 in the current study which was assessed in March 2011. The EWR study allowed for good data availability and understanding of the site and the main aim of the March 2011 sampling was to determine if the PES baseline could have changed since 2007/8 as there was uncertainties regarding the hydrology during the Reserve study.

During Jan – March 2010 high rainfall in the catchment resulted in continuously elevated flows at the site and the flows were too high to allow for biotic sampling. Although sampling could not be conducted at the site a qualitative assessment was made to determine if the PES baseline determined during 2007/08 could have changed based on the assessment of landuse activities in the area. After consultation with Mr James Mckenzie, it was decided that the condition of the vegetation and the IHI would not have changed from the Reserve assessment. Mr Piet Muller (previously from Gauteng Provincial Government: GDACE and Gauteng River Health Champion) attended the site visit and provided valuable information regarding current land use and future management strategies of the area.

4.1 SITE DESCRIPTION

Location	EWR 11	**Altitude**	1528 m
Longitude	28.42488	**Latitude**	-26.47892
EcoRegion	Highveld/Southern Central Kalahari 11.03	**Quaternary catchment**	C21F
Water Management Area	Upper Vaal	**Geomorphological zone**	Lower Foothills

EWR 11 is situated in the Blesbokspruit River downstream of the Suikerbosrand River confluence. and upstream impacts include gold mining. Surrounding land use consisted of maize and cattle farming with natural field for cattle grazing and weirs occur up and down stream of the site. The monitoring site consists of a long rapid type habitat (30m) with slow deep channel type habitat below and above it. It is expected that most of the reach in this area consists of slow deep habitat. The flow was recently very high and still high after floods in the region. Marginal aquatic vegetation was abundant for fish (Reeds - *Phragmites* sp. in areas, and *Cyperus* sp. and *Juncus* sp. – sedges). Benthic growth was excessive during previous surveys (DWA, 2010), but it is expected that high floods could have washed away some of the previously encountered filamentous algae. At the site the instream substrate consisted of rocks, cobbles and boulders in the rapids; and sandy bottom up- and down-stream of the rapid, especially on the bends. In the reach, sand as instream substrate and sedge on the margins seems to be prevalent, with rocky habitat at rapids. Deep fast flowing channel habitat was dominant at the time of the site visit.

Locally at the site a new petroleum transfer depot was erected with possible side effects to the environment (*pers. comm*. Mr. P. Muller).

Figure 4.1 Elevated flows at EWR 11 during March 2011

4.2 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 4.1. Additional information on fish, and macroinvertebrate reference conditions are also provided.

Table 4.1 EWR 11: Reference conditions

Comp	Reference conditions	Conf
Fish	Reference conditions for the site were based on the National River Health Programme (NRHP) site, C2BLES-MARAI. See Table 4.2 for a list of the reference fish species.	3
Inverts	Reference conditions are based on professional judgment and Chutter (1967), from Sites 15 and 16 (Chutter 1967: Table 11). The reference SASS5 score is 164 and the ASPT is .5.9.	3

4.2.1 Fish

Reference conditions broadly refer to "expectations on the state of aquatic biological communities in the absence of human disturbance and pollution". In the context of this report, it refers specifically to the fish species present in a particular river reach and their frequency of occurrence under reference habitat conditions. Reference conditions for the site were largely based on the NRHP site, C2BLES-MARAI (Kleynhans *et al.,* 2007b).

Ten indigenous fish species are expected under reference conditions and are listed in Table 4.2.

Table 4.2 EWR 11: Reference fish species

Expected Reference and Habitat derived FROC of fish at EWR 10 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Austroglanis sclateri	Rock-catfish	ASCL	2	0
Labeobarbus aeneus	Smallmouth yellowfish	BAEN	4	3
Barbus anoplus	Chubbyhead barb	BANO	4	2
Barbus pallidus	Goldie barb	BPAL	3	1
Barbus paludinosus	Straightfin barb	BPAU	3	1
Clarias gariepinus	Sharptooth catfish	CGAR	3	2
Labeo capensis	Orange River labeo	LCAP	4	3
Labeo umbratus	Moggel	LUMB	4	0
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	3	0
Tilapia sparrmanii	Banded tilapia	TSPA	4	4
FROC ratings: 0 = absent		3 = present at about >25 - 50 % of sites		

1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%)		4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)		
ALIEN AND INVASIVE SPECIES				
Cyprinus carpio	Common Carp	CCAR		
Gambusia affinus	Mosquito fish	GAFF		
Micropterus salmoides	Largemouth bass	MSAL		

4.2.2 Macroinvertebrates

Macroinvertebrate taxa expected under reference conditions include:
Hydropsychidae > 2 sp, Simuliidae, Heptageniidae, Ecnomidae, Elmidae/Dryopidae, Potamonautidae, Hydraenidae, Hydroptilidae, Corbiculidae, Gomphidae, Sphaeriidae, Leptophlebiidae, Aeshnidae, Dytiscidae/Noteridae, Belostomatidae, Caenidae, Ceratopogonidae, Hirudinea, Baetidae > 2 sp, Turbellaria, Oligochaeta, Coenagrionidae, Pleidae, Veliidae/M...veliidae, Gyrinidae, Chironomidae and Ancylidae.

4.3 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information provided with this report.

4.3.1 Index of Habitat Integrity (IIHI: D/E EC, 41.3%; RIHI: C EC, 64.9%)

Based on the DWA (2010) the major impact on instream habitat integrity is anthropogenic activities (e.g. mines and Sappi) and urban stormwater runoff that has caused increased runoff, water quality problems and scouring. Riparian integrity is mainly impacted by increased floods due to the anthropogenic activities and water quality problems which are causing the die off of reeds in some places and increased growth in other places.

4.3.2 Diatoms (C EC)

The Reserve results were based on four diatom samples taken at this site (August and December 2007 and January and April 2008). All four diatom samples indicate that pollution levels are extreme and that the Blesbokspruit River is of poor water quality. Organic pollution, metal contamination and salinity are a major concern and mine water decant and industrial effluent impact at critical levels. Oxygen and temperature are also variables of concern at this site. Due to the continual elevated flows the impacts are diluted constantly. The biological water quality was assessed as a C/D EC due to the dilution effect. It must however be noted that this was not a true reflection of prevailing conditions and that a slight reduction in flows would cause the biological water quality to deteriorate rapidly to a D or E category.

The diatom results have not changed significantly since 2007/08 based on additional diatom information obtained from an independent study conducted on the Blesbokspruit during 2010.

4.3.3 Fish (D EC, 48.9%)

The conditions at the site do not seem to have changed, and therefore the baseline PES has not changed since 2007/08.

Most of the expected fish species FROCs have been altered within this RU. It is expected that *A. sclate* has been lost from this reach as a result of the deteriorated water quality and the deterioration of substrate habitats (i.e. excessive benthic growth and filamentous algae). It is also expected that *L. capensis* and *L. umbratus* have also been lost, most probably as a result of water quality deterioration and loss of substrate quality (the loss of substrate in quiet water areas for LUMB, due to siltation will also reduce its FROC). The loss of slow habitats and substrate, most probably resulted in a lower FROC for species such as *B. anoplus*, *B. pallidus*, *B. paludinosus* and

L. umbratus and possibly also *C. gariepinus* with a preference for slow habitats. The presence of alien species *G. affinis* and *C. carpio* are also expected to have an impact on the indigenous species regarding breeding (egg and larvae disturbance and predation). Migration barriers in the form of weirs also affect the fish assemblages of this reach to some extent.

4.3.4 Macroinvertebrates (D/E EC, 39.8%)

For list of families present in the sample please refer to the MIRAI.
Due to the land-use activities in the catchment, the PES will remain the same. Very resistant taxa are characteristic of this site, with low to very low requirements for unmodified physic-chemical conditions. Bugs, flies, midges and snails are consistently present and dominant at this site, indicating their ability to survive in poor water quality conditions. Constant elevated flows will have a negative impact on taxa showing a preference for slow-flowing and standing water.

4.3.5 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 4.3.

Table 4.3 EWR 11: Causes and sources

	PES	Causes	Sources	F/NF
Fish	D	Altered habitat composition (slow habitats transformed to fast habitats).	Increased flows / altered hydrological regime.	F
		Altered bottom substrate habitats result in loss of fish species diversity.	Increased filamentous algal growth related to increased nutrients due to urban runoff and waste water runoff.	NF
		Decreased overhanging vegetation as cover for fish.	Grazing, agriculture and water level fluctuations.	
		Increased sedimentation result in deterioration of substrate as habitat (clogging interstitial spaces, loss of important spawning habitats, etc.).	Bank erosion, residential areas and vegetation removal (grazing) contribute to increased sedimentation. Mining.	
		Decreased species diversity and abundance (especially small species) as result of presence of predatory *G. affinis* and *M. salmoides*.	Presence of aggressive alien predatory species (*M. salmoides*) and *G. affinis* F naturally spreading and introduced for recreation / angling.	
		Decreased water quality (turbidity), and bottom substrate quality.	Impact of bottom feeding alien *C. carpio* - bio-turbation and siltation (re-suspension of silt). Mining.	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Dams and various weirs. Also farm dams in tributaries reduce refuge areas.	
Inverts	D/E	High baseflows.	Decanting mines, sewage treatment works and seepage from urban development. 2011: No mining decant at present but increased return flows from sewage works; surface run-off.	F
		Water quality problems, particularly elevated salinity and bacteria.	Industries (Mines, Sappi) and urban stormwater. 2011: Sewage treatment works; urban and industrial development; multi-purpose pipeline pump station and holding tanks in close proximity to EWR 11 – threat of leakages and spills.	NF
		Benthic algae.	Elevated nutrients and clear water.	
		Sediment (sand).	Large amount of sand from general erosion in catchment and sand mining. 2011: Localized impact from multi-purpose pipeline construction.	

4.4 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 4.4.

Table 4.4 EWR 11: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
2007/08						
Fish	D	Stable			It is estimated that the fish species have been exposed to the current impacts over a long period, and that they have adapted to the prevailing conditions.	3
Inverts	D/E	Stable			The macroinvertebrates have already adapted to the changes in the system.	3
2011						
Fish	D	Negative	E		The potential threat for the surface decanting of AMD (Acid Mine Drainage) on the East Rand,(thus the Blesbokspruit catchment) in the near future has become a reality since the pumping of underground polluted mine water at Grootvlei mine has ceased in February 2011. Underground water is currently flooding the mining tunnels and will probably result in the drop of pH of this eastern basin water body.	3
Inverts	D/E	Negative	E			3

4.5 PES ECOSTATUS

It was determined that the PES EcoStatus has not changed since 2007/08 (DWA, 2010).

4.6 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results from DWA (2010) are summarised in Table 4.5.

Table 4.5 EWR 11: EcoClassification results

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

5 OSAEH 11.13: PARYS (VAAL RIVER)

Originally it was planned to sample OSAEH 11.13 which is situated upstream of Parys in the Kromelmboogspruit which is a tributary of the Vaal River. However the site visit had to coincide with a planned PR event and an alternative site had to be selected in order to accommodate this event. A new site was selected at Parys in the Vaal River main stem.

5.1 SITE DESCRIPTION

Location:	Parys	**Altitude:**	1376 m
Longitude:	27.444185	**Latitude:**	-26.898356
EcoRegion	Highveld 11.01	**Quaternary catchment**	C23C
Water Management Area	Upper Vaal	**Geomorphological zone:**	Lower foothills

OSAEH 11.13 is situated at Parys was bedrock dominated and consisted of multiple channels. The substratum at the sampling site was slightly embedded with sediments and algae were present on some surfaces. The marginal vegetation is very well developed as a result of the available nutrients. The abundance of watercress (*Rorippa nasturtium-aquaticum*) is often an indication of excessive nutrients entering the system. The macro channel is >100 m wide at the site. The site has a diversity of instream habitats available for macroinvertebrate colonization, although filamentous algae are present on the cobbles, restricting colonization by macroinvertebrates.

Figure 5.1 Instream habitat

5.2 BIOTIC SAMPLING

5.2.1 Fish

The fish sampling was conducted at the site during October 2010. A river stretch of approximately a 100 m long, representing a variety of different depth classes, was sampled for fish along the right bank of the river. Four depth classes were sampled for 55 minutes in this stretch of river that was flowing moderately strong at the time of sampling. Sampling and data analysis was followed according to Kleynhans (2007). A summary of the site conditions during sampling is provided below. Abundance of habitat was rated as:

- 0 = absent
- 1 = rare
- 2 = sparse
- 3 = moderate
- 4 = abundant

- 5 = very abundant

Fish velocity-depth classes and cover present at the site

SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
2	3	3	3
Overhanging vegetation			
2	1	1	1
Undercut banks and root wads			
1	0	0	0
Substrate			
2	2	4	3
Aquatic macrophytes			
1	0	0	0
Water Column			
1	0	0	0

Habitats sampled and effort

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Electro shocker (min)	10 min	20 min	20 min	15 min

5.2.2 Riparian vegetation

Two sites were surveyed on the right hand bank (RB) and on the left hand bank (LB). For the assessment description the RHB site was used because it was assumed that it represented more of the natural riparian areas within the greater area. Most of the other riparian zones are totally transformed into recreational areas (picnic sites, caravan parks, housing developments, etc.). The level 3 VEGRAI was used for the assessment.

Figure 5.2 Visual of LB of site indicating recreation grounds infringing into the riparian zone

5.3 DATA AVAILABILITY

Detailed information regarding available data is provided in Table 5.1.

Table 5.1 OSAEH 11.13: Summary of data availability

Comp	Data availability	Conf
IHI	Google Earth imagery. **Department of Water Affairs and Forestry (DWAF)** 2008b. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Resource Unit. Report produced by Koekemoer Aquatic Services and Water for Africa. Authored by Louw, D. Report no: RDM/WMA8 C000/01/CON/0208.	3
Riparian vegetation	Google Earth imagery. Data collected from field assessment during October 2010. Literature: **Kleynhans C.J, MacKenzie J., Louw M.D.** 2007a. Module F: Riparian Vegetation Response Assessment Index in River Classification: Manual for EcoStatus Determination (version 2). Joint Water Commission and Department of Water Affairs and Forestry report. WRC Report No. TT333/08. **Low B.A., Rebello A.G.** (eds) 1998. Vegetation of South Africa, Lesotho and Swaziland**.** Department of Environmental Affairs and Tourism, Pretoria. **Mucina L. & Rutherford M.C**. (eds) 2005. VEGMAP. Wall Map South African National Biodiversity Institute, Pretoria. **Mucina L. & Rutherford M.C.** (eds) 2006. Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19*. South African National Biodiversity Institute, Pretoria. **Van Wyk B. & Van Wyk P**. 2009. Field Guide to trees of Southern Africa. 12th Impression. Struik Nature Publishers, Cape Town.	2
Fish	One site visit and fish sampling during October 2010. South African Institute of Aquatic Biodiversity (SAIAB) data base (2006). **Kleynhans, C.J., Louw, M.D & Moolman, J**. 2007b. Module D (Volume 2): Reference Frequency of Occurrence of Fish Species in South Africa: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry Report. WRC Report No. TT330/08. Water Research Commission, Pretoria, South Africa.	3
Inverts	SASS5 surveys undertaken to determine the PES (Rivers Database) and October 2010.	2

5.4 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 54.2. Additional information on fish, macroinvertebrate and riparian vegetation reference conditions are also provided.

Table 5.2 OSAEH 11.13: Reference conditions

Comp	Reference conditions	Conf
Riparian vegetation	**Marginal zone:** Grass dominated state (including sedges). Exotic species would be replaced by indigenous species, such as *Pennisetum macrourum, Persicaria senegalensis, Schoenoplectus corymbosus, Juncus effusus,* etc. No exotic trees such as *Eucalyptus* sp. and *Salix babylonica* should occur. Less water quality problems should occur. **Non-marginal zone:** Grass and shrub dominated state. More indigenous grass and cover should be present. Less exotic pioneers and terrestrial species are expected. No Picnic and recreation disturbances should be present. Without impacts the response metrics should be better on all accounts. More indigenous grass species and cover should be present, such as *Cynodon dactylon*, *Sporobolus africanus, Setaria sphacelata, Digitaria eriantha,* etc. Less terrestrial species should be present such as *Protasparagus laricinus*. Riparian vegetation species also expected under reference conditions include the following: *Setaria incrassata, Setaria sphacelata, Sporobolus africanus, Pennisetum macrourum, Digitaria eriantha, Persicaria senegalensis, Juncus effusus, Gymnosporia buxifolia, Rhus buxifolia, Cyperus esculentus, Schoenoplectus corymbosus*.	3
Fish	Reference conditions for the site were based on the National River Health Programme (NRHP) site, **C2VAAL-PARYS.** See Table 4.3 for a list of the reference fish species.	4
Inverts	Reference conditions are based on professional judgement and Rivers Database information. The reference South African Scoring System version 5 (SASS5) score is 230 and the Average Score Per Taxon (ASPT) is 6.5.	3

5.4.1 Fish

Reference conditions broadly refer to "expectations on the state of aquatic biological communities in the absence of human disturbance and pollution". In the context of this report, it refers specifically to the fish species present in a particular river reach and their frequency of occurrence under reference habitat conditions. Reference conditions for the site were largely based on the NRHP site, **C2VAAL-PARYS** (Kleynhans *et al.,* 2007b). Although the national RHP sites refer to a specific site, it is representative of the river reach downstream of Vaal Dam down to the Bloemhof Dam.

Based on the available information and professional judgement the following alterations were made for the purpose of this site:

- *Barbus anoplus* were omitted from the expected list as this species mainly occur in smaller tributaries of the Vaal River and are unlikely to occur in the main stem.
- *Barbus paludinosus and Barbus trimaculatus* were were included in the expected list as these species were present at the site during recent site visit.

Ten indigenous fish species are expected under reference conditions and are listed in Table 5.3.

Table 5.3 OSAEH 11.13: Reference fish species

Expected Reference and Habitat derived FROC of fish at OSAEH 11.13 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Austroglanis sclateri	Rock catfish	ASCL	3	1
Barbus paludinosus	Straightfin barb	BPAU	3	3
Barbus trimaculatus	Threespot barb	BTRI	3	1
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Labeo capensis	Orange River labeo	LCAP	5	5
Labeo umbratus	Moggel	LUMB	3	1
Labeobarbus aeneus	Smallmouth yellowfish	BAEN	4	4
Labeobarbus kimberleyensis	Largemouth yellowfish	BKIM	3	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	4
Tilapia sparrmanii	Banded tilapia	TSPA	3	1
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%) 3 = present at about >25 - 50 % of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)				
ALIEN AND INVASIVE SPECIES				
Ctenopharyngodon idella	Grass Carp	CIDE		
Cyprinus carpio	Common Carp	CCAR		
Gambusia affinus	Mosquito fish	GAFF		
Micropterus salmoides	Largemouth bass	MSAL		

5.4.2 Macroinvertebrates

Macroinvertebrate taxa expected under reference conditions include:
Perlidae, Hydropsychidae (>2 spp.), Heptageniidae, Baetidae (>2 spp.), Tricorythidae, Elmidae/Dryopidae, Atyidae, Leptophlebiidae, Hydracarina, Simuliidae, Coenagrionidae, Naucoridae, Ecnomidae, Philopotamidae, Hydroptilidae, Tipulidae, Corbiculidae, Caenidae, Gerridae, Veliidae, Dytiscidae, Gyrinidae, Psephenidae, Ceratopogonidae, Porifera, Hydrophilidae, Turbellaria, Potamonautidae, Corixidae, Chironomidae, Sphaeriidae, Oligochaeta, and Hirudinea.

5.5 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information provided with this report.

5.5.1 Index of Habitat Integrity (IIHI: C/D EC 57.5%; RIHI: C EC, 63.6%)

The IIHI was rated a C/D (57.5%). This is mostly due to changes in water quality as a result of extensive upstream urban and mining runoff as well as some cultivation. The hydrology has also changed significantly due to upstream inundation and flow modification. The RIHI is a C (63.3%) the main impacts being bank modification in the marginal and non-marginal zones due to altered hydrological regimes, an increase in exotic vegetation, riparian irrigation, trampling, erosion and vegetation removal.

5.5.2 Diatoms (D EC)

The October 2010 sample indicated moderately polluted waters with low organic levels and elevated nutrient levels. A release was made a few days before sampling and this could have had a dilution effect of pollutants. This reach is known for deteriorated water quality at times as sewage is discharged just upstream of the site by Parys municipality. The overall EC of a C/D is based on data used for the Reserve study (DWA, 2010 a[1]), and it should be noted that salinity levels along with nutrient and organic levels do increase to critical levels in this reach at times.

5.5.3 Fish (C EC, 62.3%)

Six of the ten expected fish species were collected within this Resource Unit (RU) during the present survey suggesting that the FROC of some species has been reduced from reference conditions. Based on their absence or low abundance of smaller species such as *B. trimaculatus*, *B. paludinosus, P philander* and *T sparrmanii* the FROC at this site was rated to be reduced from reference. Although *L umbratus and L. kimberleyensis* was not collected at this site during the present survey, the sampling site did not provide suitable habitat for these species.

5.5.4 Macroinvertebrates (C EC, 77.3%)

Macroinvertebrates were sampled using the standard SASS5 method. Habitats sampled include Stones In Current (SIC), Stones Out of Current (SOOC), Marginal Vegetation In Current (MVIC), Marginal Vegetation Out of Current (MVOOC), Gravel, Sand and Mud (GSM), bedrock and boulders. For list of families present in the sample please refer to the MIRAI.

SASS results:

	SASS5 score: 166	No of Taxa: 30	ASPT: 5.5
October 2010:	SASS5 score: 126	No of Taxa: 22	ASPT: 5.7

Key taxa expected but not observed included Aeshnidae and Libellulidae. Hirudinea, Dytiscidae, Tricorythidae and Elmidae were more abundant than expected, while Heptageniidae were less abundant than expected.

5.5.5 Riparian vegetation (C EC, 71.5%)

The assessment was done using VEGRAI level 3. This site occurs within the Vredefort Dome Granite Grassland vegetation type, which has an endangered conservation status with 0% protected. Almost half of this vegetation type is already transformed by cultivation (maize fields), by urban development or by road building.

[1] **Department of Water Affairs (DWA).** 2010a. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EcoClassification Report: Volume 1. Report produced by Koekemoer Aquatic Services and Rivers for Africa. Edited by Louw, D and Koekemoer, S. Report no: RDM/ WMA8 C000/01/CON/0109.

Marginal Zone:
This zone is currently in a grass and sedge dominated state. The active channel is wide with several islands. Many sedge clumps occur between rocky areas in rock cracks. Little to no bare patches arise in between. The rocky substrate is dominant. Some *Rhus pyroides, Salix babylonica* and *Eucalyptus* sp. trees are present. Impacts consist mainly of picnic related activities and the encroachment of pioneering exotic vegetation such as *Pennisetum clandestinum, Verbena bonariensis, Persicaria lapathifolia.* Other vegetation that occurs in this zone is *Phragmites australis, Veronica Anagallis-aquatic, Cyperus excalenthes, Cyperus marginata, Cyperus eragrostis, Crinum bulbispermum*. Good cover and abundance occur. Indication of enrichment of water can contribute to excessive growth of vegetation.

Non-marginal zone:
This zone is currently in a grass and shrub dominated state. Impacts consist mainly of picnic (recreation in the form of footpaths) and exotic (pioneer) species. The exotic trees occurring in this zone are *Gleditsia triacanthos, Melia azedarach, Ulmus parvifolia, Eucalyptus* sp. and *Salix babylonica*. Bank substrate consists mainly of rocks and soil. A well defined high flow channel exists in the non-marginal zone and is covered mainly with grasses and exotic (pioneer) species such as *Verbena tenuisecta, Verbena bonariensis, Pheusodognaphalia luteo-album, Melilotus indica, Tagetes minuta, Cyclospermum leptophyllum, Cirsium vulgare*. The cover is good in this zone.

5.5.6 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 5.4.

Table 5.4 OSAEH 11.13: Causes and sources

	PES	Causes	Sources	F/NF
Rip veg	C	Footpaths and firewood collection.	Picnic and recreation facilities in and adjacent to study site.	NF
		Exotic invasion.	*Salix babylonica, Gleditsia triacanthos,* and *Eucalyptus* sp., and the site has non-woody weeds.	
		Water quality.	Chicken farms, non-point pollution, sewage plants, recreation facilities, etc. Housing developments on the banks of the Vaal River.	F
Fish	C	Loss of habitat diversity as a result of flow modification.	Inundation upstream and flow modification.	F
		Decreased water quality affect species with requirement for high water quality.	Increased nutrients, sediments and toxins from urban areas diamond & gold mines and agricultural areas.	NF
		Increased turbidity and disturbed bottom substrates.	Erosion and presence of bottom feeding alien (*C carpio*).	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Major upstream and downstream dams as well as weirs.	
Inverts	C	Sedimentation.	Urbanization and agriculture.	NF
		Water quality and associated benthic growth.	Agriculture and urbanization.	

5.6 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 5.5.

Table 5.5 OSAEH 11.13: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Rip veg	C	Stable			Habitat availability has defined the current condition of riparian zone integrity. The riparian vegetation has responded and it is improbable that current situation will change remarkably so as to affect the current EC.	3
Fish	C	Stable			No other new influences could be identified that would cause a direction change in the Present Ecological State of the fish assemblage.	3
Inverts	C	Stable			The macroinvertebrates have already reacted to the current conditions.	3

5.7 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 5.6. The Instream EC is a C (68.3%).

Table 5.6 OSAEH 11.13: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	2.5	90		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	2	80		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2	80		
FISH ECOLOGICAL CATEGORY	9.5	350	**62.3**	**C**
MACROINVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	3	100		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	3	100		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	90		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**8**	290	**77.3**	**C**
INSTREAM ECOLOGICAL CATEGORY (Excl confidence)		640	**71.3**	**C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	3	0.60	37.38	
Confidence rating for **macroinvertebrate** information	2	0.40	30.92	
	5	1.00	68.30	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**C**	

To determine the EcoStatus, the Vegetation Response Assessment Index (VEGRAI) EC and confidence is included in the EcoStatus assessment index (Table 5.7). The EcoStatus EC is a C.

Table 5.7 OSAEH 11.13: Instream EC

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	71.5	C	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	2.6	0.42	28.64
Confidence rating for riparian vegetation zone information	3.6	0.58	41.52
	6.2	1.00	70.16
ECOSTATUS	EC		C

5.8 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised in Table 5.8.

Table 5.8 OSAEH 11.13: EcoClassification results

Driver Components	PES	Trend
IHI: INSTREAM	C/D	
IHI: RIPARIAN	C	
DIATOMS (WQ)	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	C	Stable
ECOSTATUS	C	

5.9 SUITABILITY AS FUTURE MONITORING SITE

5.9.1 Biotopes present

This site has diverse instream habitat available for SASS sampling. Good quantity of cobbles, marginal vegetation in and out of current, stones out of current and GSM biotopes are available. Algal growth is present on the cobble biotope. The site is easily accessible with wadeable areas. The fast deep habitat provides suitable habitat for larger fish species. The diversity of substratum provides good cover for all fish species. The site provides an abundance of undercut banks, marginal and overhanging vegetation as suitable habitat for small fish species. The marginal riparian zone has relatively good vegetation cover. No erosion is present in the marginal zone, although localised impacts are present along with exotic vegetation.

Component	Advantages	Disadvantages	Conf
Rip veg	Easily accessible Riparian zone (marginal and non-marginal) with relatively good vegetation cover Well defined hydro-geomorphic zones No infrastructure in riparian zone No erosion	Exotic species (pioneer species) Poor water quality Picnic and other recreation related activities Several localised impacts Housing developments adjacent to study area Terrestrialisation	3
Fish	Easily accessible with wadeable areas. Fast Deep provided suitable habitat for larger species Diversity of substratum provided good cover for all species. Abundance of undercut banks and marginal and/or overhanging vegetation provided suitable habitat for small species.	Substratum slightly imbedded with sediments Low diversity of flow velocities	4
Inverts	Good quantity of cobble biotope present Diversity of instream habitats present Good quality and quantity of marginal vegetation Diversity of velocities present	Algal growth on cobble biotope Localised impacts include a picnic site and caravan park	3

5.9.2 Site suitability

The site suitability of each site was assessed and is provided in Table 5.9. All scores are out of 5 with 5 referring to very high suitability (see below).

Very High: 4.1 – 5 High: 3.1 – 4

Moderate: 2.1 – 3 Low: 1.1 – 2

Very Low: 0 – 1

Table 5.9 OSAEH 11.13: Biophysical site suitability

Site	Rip veg	Fish	Inverts	Average	Median	Max	Min	Comments
OSAEH 11.13	2	3	3	2.67	3	3	2	**Moderate** suitability for biotic component monitoring, but a difficult site to assess for riparian vegetation as it is an anastomosing site with channel width over 400 m and banks have been altered. Flow is also regulated and manipulated.

6 OSAEH 11.3: MOOI RIVER

6.1 SITE DESCRIPTION

Location	OSAEH 11.3	**Altitude**	1393 m
Longitude	27.09856	**Latitude**	-26.68283
EcoRegion	Highveld 11.01 & 11.08	**Quaternary catchment**	C23H
Water Management Area	Upper Vaal	**Geomorphological zone**	Foothill

This site is situated in a park, in a residential area surrounded by plots approximately 1.6 km downstream of Potchefstroom Dam. The site constitutes a small, perennial stream with a dominant clay substrate, with riffles, runs and pools characterising the system. The stream is approximately 2 m in width and approximately 15 m in width at the pool areas. No local erosion exists. Bank undercutting is abundant, with exotic trees dominating the riparian vegetation. The river is incised and no channel modification is present at the site. Bed modification exists due to extensive siltation of the stream bed. No free floating algae and benthic algae were present. The marginal riparian zone is narrow, incised and mostly open due to extensive shading from alien woody species, especially taller trees such as *Salix babylonica* and *Populus sp*.

Figure 6.1 OSAEH 11.3

6.2 BIOTIC SAMPLING

6.2.1 Fish

The fish sampling was conducted at the site on 25 October 2010. A river stretch of approximately a 150 m long, was sampled representing mostly pool (1 - 1.5 m deep), riffle (0.3 m deep), run (0.4 m deep) and pool habitat. Four depth classes were sampled for 45 minutes in this stretch of river. Sampling and data analysis was followed according to Kleynhans (2007). A summary of the site conditions during sampling is provided below. Abundance of habitat was rated as:

- 0 = absent
- 1 = rare
- 2 = sparse
- 3 = moderate
- 4 = abundant
- 5 = very abundant

Fish velocity-depth classes and cover present at the site

SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
4	4	0	3
Overhanging vegetation			
4	4	0	4

Undercut banks and root wads			
5	5	0	5
Substrate			
1	1	0	1
Aquatic macrophytes			
0	0	0	0
Water Column			
5	3	0	2

Habitats sampled and effort

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Electro shocker (min)	25 min	10 min	0 min	10 min

6.3 DATA AVAILABILITY

Detailed information regarding available data is provided in Table 6.1.

Table 6.1 OSAEH 11.3: Summary of data availability

Comp	Data availability	Conf
IHI	Google Earth imagery. **Department of Water Affairs and Forestry (DWAF)** 2008b. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Resource Unit. Report produced by Koekemoer Aquatic Services and Water for Africa. Authored by Louw, D. Report no: RDM/WMA8 C000/01/CON/0208.	3
Riparian vegetation	Google Earth imagery. Current Google Earth imagery of the site and site context. Data collected from field assessment during October 2010. Ecological reports and specialist assessments for this study; previous Reserve determination report SANBI floristic distribution data (2009) Literature: **Kleynhans C.J, MacKenzie J., Louw M.D.** 2007a. Module F: Riparian Vegetation Response Assessment Index in River Classification: Manual for EcoStatus Determination (version 2). Joint Water Commission and Department of Water Affairs and Forestry report. WRC Report No. TT333/08. **Low B.A., Rebello A.G.** (eds) 1998. Vegetation of South Africa, Lesotho and Swaziland**.** Department of Environmental Affairs and Tourism, Pretoria. **Mucina L. & Rutherford M.C.** (eds) 2006. Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19*. South African National Biodiversity Institute, Pretoria. **Van Wyk B. & Van Wyk P**. 2009. Field Guide to trees of Southern Africa. 12th Impression. Struik Nature Publishers, Cape Town.	4
Fish	Google Earth imagery. One site visit and fish sampling during October 2010. South African Institute of Aquatic Biodiversity (SAIAB) data base (2006). **Kleynhans, C.J., Louw, M.D & Moolman, J**. 2007b. Module D (Volume 2): Reference Frequency of Occurrence of Fish Species in South Africa: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry Report. WRC Report No. TT330/08. Water Research Commission, Pretoria, South Africa. **Rivers Data base** (2007): *Database on fish distribution in South African Rivers*. **Scott *et al.*** (2006): *Atlas of Southern African Freshwater Fishes*.	3
Inverts	Google Earth imagery. One site visit and fish sampling during October 2010. SASS5 surveys undertaken to determine the PES (Rivers Database).	3

6.4 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 6.2. Additional information on fish, macroinvertebrate and riparian vegetation reference conditions are also provided.

Table 6.2 OSAEH 11.3: Reference conditions

Comp	Reference conditions	Conf
Riparian vegetation	Grassland Biome, with Rand Highveld Grassland vegetation type (Mucina and Rutherford, 2006). **Marginal and Lower Zones:** Dominated by non-woody vegetation, a mix of sedges and hydrophylic dicots and grasses. A small fairly low woody component expected, mainly *Salix mucronata.* **Upper Zone:** Dominated by grasses in keeping with the Vegetation Type Upper Zone macro channel bank (MCH): Dominated by grasses (mainly terrestrial grasses), with woody components where substrate becomes rocky and steep (*Diospyros lycioides* mainly).	3
Fish	Reference conditions as set for the NRHP site, C2MOOIMEULS, (Kleynhans *et al.,* 2007b), which is also the OSEAH 11.3 sampling site, was used as a starting point for setting reference conditions. See Table 5.3 for a list of the reference fish species.	3
Inverts	Reference conditions are based on professional judgement and Rivers Database information. The reference SASS5 score is 220 and the ASPT is 7.0.	2

6.4.1 Fish

Reference conditions broadly refer to "expectations on the state of aquatic biological communities in the absence of human disturbance and pollution". In the context of this report, it refers specifically to the fish species present in a particular river reach and their frequency of occurrence under reference habitat conditions. Reference conditions for the site were largely based on the NRHP site, C2MOOIMEULS (Kleynhans *et al.,* 2007b), which is also the OSEAH 11.3 sampling site, was used as a starting point for setting reference conditions.
Professional opinion and experience; sampling; and habitat and site observations were further used to obtain a derived FROC from the reference FROC, based on the species habitat and condition preferences and tolerances (Table 6.3).

Twelve indigenous fish species are expected under reference conditions and are listed in Table 6.3. An exotic fish species *Gambusia affinis* was also sampled.

Table 6.3 OSAEH 11.3: Reference fish species

Expected Reference and Habitat derived FROC of fish at OSAEH 11.3 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Austroglanis sclateri	Rock-catfish	ASCL	1	0
Labeobarbus aeneus	Smallmouth yellowfish	BAEN	1	1
Barbus anoplus	Chubbyhead barb	BANO	3	2
Labeobarbus kimberleyensis	Largemouth yellowfish	BKIM	3	0
Barbus neefi	Sidespot barb	BNEE	1	1
Barbus paludinosus	Straightfin barb	BPAU	3	1
Barbus trimaculatus	Threespot barb	BTRI	1	1
Clarias gariepinus	Sharptooth catfish	CGAR	3	3
Labeo capensis	Orange River labeo	LCAP	1	1
Labeo umbratus	Moggel	LUMB	3	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	3	3
Tilapia sparrmanii	Banded tilapia	TSPA	1	1
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%) 3 = present at about >25 - 50 % of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)				
ALIEN AND INVASIVE SPECIES				
Gambusia affinis	Mosquito fish	GAFF		

6.4.2 Macroinvertebrates

Macroinvertebrate taxa expected under reference conditions include:
Hydropsychidae (>2spp), Naucoridae, Gyrinidae, Caenidae, Tipulidae, Corbiculidae, Gomphidae, Pleidae, Dytiscidae, Hydrophillidae, Haliplidae, Coenagrionidae, Hydrophilidae, Libelullidae, Ceratopogonidae, Simuliidae, Porifera, Ancylidae, Leptoceridae, Baetidae (2spp), Gerridae, Vellidae, Hydracarina, Chlorolestidae, Hydraemidae, Atyidae, Elmidae, Aeshnidae, Notonectidae, Corrixidae, Sphaeridae, Oligochaeta, Belostomatidae, Planorbidae, Thiaridae, Potamonautidae, Turbellaria, and Chironomidae.

6.5 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information provided with this report.

6.5.1 Index of Habitat Integrity (IIHI: C EC, 65.7%; RIHI: D/E EC, 39%)

The IIHI is a C (65.7%), mostly due to poor bed and bank conditions, especially since the riparian component is highly altered, as well as altered flow regimes and deteriorating water quality from large dams upstream of the site. The RIHI is a D/E (39%) with the main impacts being poor bank conditions due to a high degree of manipulation of geomorphic features and extreme density and cover of perennial and annual alien vegetation, some of which have been planted.

6.5.2 Diatoms (D EC)

The assessment is based on the site visit as well as data collected as part of a MSc study (Koekemoer, 2010). The diatom community is typical of urban waters with nutrient and organic pollution levels becoming critically elevated at times. Due to industrial activity salinity is also elevated. The EC is a D.

6.5.3 Fish (D EC, 50.6%)

Most of the fish species expected under reference conditions are still expected to be present under the present conditions at this site, although the FROC of some species have been reduced from reference conditions. These are mainly moderately tolerant to tolerant species. The main impacts on these fish are decreased flows, loss of water column in FD and FS as cover, siltation and loss of substrate as cover, and the absence of aquatic macrophytes. The presence of *Gambusia affinis*, which preys on fish eggs and larvae, will also negatively impact on the fish species present in the system.

Two species *Labeobarbus kimberleyensis* and *Austroglanis sclateri* are however not expected to occur anymore due to a loss of their preferred habitat. The main impacts on these fish are decreased flows, loss of water column in FD and FS as cover, siltation and loss of substrate (cobbles and rock) as cover.

Damming of the stream due to fallen woody debris and dead trees (exotics) also reduce fast flowing habitats, and alter habitat and water quality. This seems to be the major impact at the site.

6.5.4 Macroinvertebrates (D EC, 48.1%)

Macroinvertebrates were sampled using the standard SASS5 method. Habitat available was Stones in current (SIC), Stones out of current (SOOC), Marginal vegetation out of current (MVOC), Gravel sand and mud (GSM) and Aquatic vegetation (AV). For list of families present in the sample please refer to the MIRAI.

SASS results:

October 2010: SASS5 score: 97 No of Taxa: 20 ASPT: 4.86

Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as those of genus Hydropsychidae (>2spp), Heptageniidae, Perlidae, Philopotamidae, Psephenidae, Chlorocyphidae, Athericidae, Tricorythidae and Leptophlebidae. However, Baetidae (>2spp) was expected and found on site as expected under reference conditions. Most of taxa observed during the time of sampling were generally those with low to moderate requirement in water quality.

6.5.5 Riparian vegetation (E EC, 27.7%)

The assessment was done using VEGRAI level 4.

Marginal Zone:

The zone is narrow, incised, and mostly open due to extensive shading from alien woody species, especially taller trees such as *Salix babylonica* and *Populus sp*. Mostly open fine alluvium or dominated by exposed roots

Lower Zone:

This zone is the same as the marginal zone, with large cover by *Pyracantha angustifolia*.

Upper Zone and MCB:

RB: Dominated by mowed parkland with planted alien trees which cause intense shading, dominant non-woody species is *Bromus catharticus** and several weed species.

LB and mid-channel bar: Extensively dominated by dense woody vegetation and deep shade, mostly alien species, especially *Ligustrum** species, but also with *Celtis africana, Searsia pyroides, S. lancea* and some open grassed areas on the terrace with a healthy population of *Crinum bulbispermum* (declining) (* indicates invasive alien species).

6.5.6 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 6.4.

Table 6.4 OSAEH 11.3: Causes and sources

	PES	Causes	Sources	F[1]/NF[2]
Rip veg	E	Significantly reduced cover of indigenous riparian obligate species, especially in the marginal and lower zones.	Severe shading from tall and dense alien woody species overhanging.	NF
		Altered species composition.	High cover (up to 70%) and density of perennial alien species , and mowing of upper zone terraces.	
Fish	D	Loss of habitat (decreased FD and FS) diversity as a result of flow modification (especially during natural low flow periods).	Dam, water abstraction for plots/irrigation, urbanization.	F
		Decreased substrate quality due to embedding.	Lower than natural flushes and floods.	
		Loss of FD and FS habitat.	Damming of stream due to fallen exotic trees and woody debris.	NF
		Decreased aquatic vegetation as cover for fish.	Increased exotic riparian vegetation and shading. Less light penetration – very shaded.	
		Lower oxygen and temperature levels.	Exotic trees causing excessive shading.	
		Increased sedimentation resulting in deterioration of substrate as habitat (clogging and loss of important spawning habitats, and cover etc.).	Upstream bank erosion due to urbanization, and developments.	
		Decreased species diversity and abundance due to presence of *G. affinis*.	Presence of alien predatory species (*G. affinis*) introduced for aquariums and mosquito control.	
		Enrichment of water and anaerobic decomposition.	Fallen woody debris and trees (exotics).	
		Possible pollution and enrichment of water.	Urbanization.	

	PES	Causes	Sources	F[1]/NF[2]
		Presence of dams and weirs as migration barriers (breeding, feeding and dispersal), also causing loss of habitat of some species (inundation).	Potchefstroom Dam and other smaller weirs in area.	
Inverts	D	Lack of key habitat.	Urbanization and agriculture.	F
		Poor water quality and associated benthic growth.	Agriculture and urbanization.	NF

6.6 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 6.5.

Table 6.5 OSAEH 11.3: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Rip veg	E	Negative	E/F	>5 years	Alien woody species will continue to form dense stands, which will exclude recruitment by indigenous species and exacerbate the impacts noted above	3
Fish	D	Stable			The site was surveyed during the dry season base flow period (low flow), and there was still adequate flow present (ample FS) to sustain fish in pools or refuge areas. Only no flow periods, and the introduction of other alien fish species could affect the fish PES further. The fish seem to have adapted to the current conditions.	2.5
Inverts	D	Stable			The macroinvertebrates have already reacted to the current conditions.	1

6.7 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 6.6. The Instream EC is a D (49.6%).

Table 6.6 OSAEH 11.3: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	4	80		
2.What is the natural diversity of **fish** species with a preference for different cover types	5	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	4	80		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	70		
FISH ECOLOGICAL CATEGORY	16	330	**50.6**	**D**
MACROINVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	2	100		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	2	100		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	100		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**6**	300	**48.1**	**D**
INSTREAM ECOLOGICAL CATEGORY (Excl confidence)		630	**49.6**	**D**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	

Confidence rating for **fish** information	3	0.60	30.36
Confidence rating for **macroinvertebrate** information	2	0.40	19.24
	5	1.00	49.60
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**D**

To determine the EcoStatus, the Vegetation Response Assessment Index (VEGRAI) EC and confidence is included in the EcoStatus assessment index (Table 6.7). The EcoStatus EC is an E.

Table 6.7 OSAEH 11.3: Instream EC

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**27.7**	**E**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	2.6	0.41	20.15
Confidence rating for riparian vegetation zone information	3.8	0.59	16.45
	6.4	1.00	36.60
ECOSTATUS	**EC**		**E**

The EcoStatus is an E, mainly due to the poor condition of the riparian vegetation, which is impacted by exotic species. During future monitoring, the focus should be on the instream condition during (D EC).

6.8 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised in Table 6.8.

Table 6.8 OSAEH 11.3: EcoClassification results

Driver Components	PES	Trend
IHI: INSTREAM	C	
IHI: RIPARIAN	D/E	
DIATOMS (WQ)	D	
Response Components	**PES**	**Trend**
FISH	D	Stable
MACRO INVERTEBRATES	D	Stable
INSTREAM	D	
RIPARIAN VEGETATION	E	Negative
ECOSTATUS	**E**	

6.9 SUITABILITY AS FUTURE MONITORING SITE

6.9.1 Biotopes present

Low instream habitat diversity is available for SASS sampling. Biotopes present include good quality but moderate quantity of cobble biotope present. Moderate Gravel, Sand & Mud (GSM) biotope is present, with moderate overhanging marginal vegetation available. Limited Stones Out Of Current (SOOC) is present as well as low diversity of velocities present.

The Mooi River is a perennial stream and is highly impacted by urban disturbances, pollution, and siltation (substrate embedded) and therefore habitat diversity is reduced. Bank undercutting, root wads and overhanging vegetation are abundant for fish cover, however there is an absence of substrate (rocks and cobbles), and siltation may be a limiting factor at the site (mainly muddy/clay bottom). Pools are abundant and provide water column cover and refugia for fish species. Limited cobble biotope is present and no Fast Deep (FD) flow depth class is present.

An abundance of exotic riparian vegetation exists, with increased instream siltation and solid waste disposal present. Alluvial habitat is available in the riparian zone and a good geophyte population is present. Extremely high coverage by alien perennial vegetation exists in the riparian zone. A limited availability of indigenous riparian species are present in the riparian zone.

The site is not adequate for monitoring. The RHP site below Mooi River Mall has been flooded due to development and therefore no site exists downstream of the Mall and no other suitable site could be found. It must however be noted that the Mooi River impacts are driven by water quality problems, and before a catchment management plan is not initiated in this system the biotic condition in the Mooi will not be improved. The Mooi has also been significantly altered. This site is not considered a high priority site for future monitoring.

Component	Advantages	Disadvantages	Conf
Rip veg	Riparian alluvial habitat available Good geophyte population	Extremely high coverage by alien perennial vegetation Limited availability of indigenous riparian species Site modified to form recreational parkland	5
Fish	Perennial stream 75% diversity of flow depth classes present Few localised impacts Relative diversity of instream habitats present Bank undercut, rootwads, and overhanging veg abundant for fish cover. Pools abundant for water column cover and refugia. No excessive benthic growth Two small limnophilic species expected and their habitat is well represented at the site.	Limited cobble (substrate) biotope present No FD flow depth class present (will be during high flows) Abundant exotic riparian veg. High siltation Solid waste disposal No aquatic vegetation No rheophilic species expected. Four large and four small semi-rheophilic spp. expected. Their required habitat not very well represented at site.	3
Inverts	Good quality but moderate quantity of cobble biotope present Moderate GSM biotope present Moderate overghanging marginal vegetation	Limited SOOC biotope present Low diversity of velocities present Low diversity of in-stream habitats present	3

6.9.2 Site suitability

The site suitability of each site was assessed and is provided in Table 6.9. All scores are out of 5 with 5 referring to very high suitability (see below).

Very High: 4.1 – 5 High: 3.1 – 4
Moderate: 2.1 – 3 Low: 1.1 – 2
Very Low: 0 – 1

Table 6.9 OSAEH 11.3: Biophysical site suitability

Site	Rip veg	Fish	Inverts	Average	Median	Max	Min	Comments
OSAEH 11.3	1	3	2	2.00	2	3	1	**Low** suitability for biotic component monitoring. Habitat diversity is low. A large portion of the site is a park which is mowed and this landuse is unlikely to change.

7 OSAEH 11.6: RHENOSTERSPRUIT

7.1 SITE DESCRIPTION

Location	Rhenostersprui t	**Altitude**	1308m
Longitude	27.0099	**Latitude**	-27.0529
EcoRegion	Highveld 11.08	**Quaternary catchment**	C70K
Water Management Area	Middle Vaal	**Geomorphological zone**	Lowland River

OSAEH 11.6 is situated approximately 18 km upstream of its confluence with the Vaal River adjacent to the R501 road crossing close to a farm household (Figure 7.1). An old cement bridge also occurs between the site and the road crossing. This site extends from a dark rocky dyke downstream of the abandoned cement bridge and follows the river downstream to an open water area (± 200 m). The water was slightly turbid and the river channel was notably stable with well developed marginal vegetation. The abundance of watercress (*Rorippa nasturtium-aquaticum*) is often an indication of excessive nutrients entering the system. The substratum at the sampling site was slightly embedded and benthic algae were also present. There is abundant, diverse marginal vegetation, with good cobble habitat available if suitable flow is present. GSM (Gravel, Sand and Mud) and SOOC (Stones Out Of Current) biotopes were also present in suitable quantity and quality.

Figure 7.1 OSAEH 11.6

7.2 BIOTIC SAMPLING

7.2.1 Fish

The fish sampling was conducted at the site during October 2010. A river stretch of approximately a 100 m long, representing mostly slow deep and slow shallow depth classes, was sampled for fish as the flow was very low at the site resulting in scarce fast shallow and fast deep habitat. Four depth classes were sampled for 40 minutes in this stretch of river. Sampling and data analysis was followed according to Kleynhans (2007). A summary of the site conditions during sampling is provided below. Abundance of habitat was rated as:

- 0 = absent
- 1 = rare
- 2 = sparse

- 3 = moderate
- 4 = abundant
- 5 = very abundant

Fish velocity-depth classes and cover present at the site

SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
1	4	1	1
Overhanging vegetation			
1	1	1	1
Undercut banks and root wads			
0	0	0	0
Substrate			
0	3	1	1
Aquatic macrophytes			
0	0	0	0
Water Column			
1	0	0	0

Habitats sampled and effort

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Electro shocker (min)	5 min	20 min	5 min	105 min

7.3 DATA AVAILABILITY

Detailed information regarding available data is provided in Table 7.1.

Table 7.1 OSAEH 11.6: Summary of data availability

Comp	Data availability	Conf
IHI	Google Earth imagery. **Department of Water Affairs and Forestry (DWAF)** 2008b. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Resource Unit. Report produced by Koekemoer Aquatic Services and Water for Africa. Authored by Louw, D. Report no: RDM/WMA8 C000/01/CON/0208.	3
Riparian vegetation	Google Earth imagery. Data collected from field assessment during October 2010. Literature: **Kleynhans C.J, MacKenzie J., Louw M.D.** 2007a. Module F: Riparian Vegetation Response Assessment Index in River Classification: Manual for EcoStatus Determination (version 2). Joint Water Commission and Department of Water Affairs and Forestry report. WRC Report No. TT333/08. **Low B.A., Rebello A.G.** (eds) 1998. Vegetation of South Africa, Lesotho and Swaziland**.** Department of Environmental Affairs and Tourism, Pretoria. **Mucina L. & Rutherford M.C**. (eds) 2005. VEGMAP. Wall Map South African National Biodiversity Institute, Pretoria. **Mucina L. & Rutherford M.C.** (eds) 2006. Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19*. South African National Biodiversity Institute, Pretoria. **Van Wyk B. & Van Wyk P**. 2009. Field Guide to trees of Southern Africa. 12th Impression. Struik Nature Publishers, Cape Town.	3
Fish	One site visit and fish sampling during October 2010. South African Institute of Aquatic Biodiversity (SAIAB) data base (2006). **Kleynhans, C.J., Louw, M.D & Moolman, J**. 2007b. Module D (Volume 2): Reference Frequency of Occurrence of Fish Species in South Africa: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry Report. WRC Report No. TT330/08. Water Research Commission, Pretoria, South Africa.	3
Inverts	SASS5 surveys undertaken to determine the PES (Rivers Database) during May 2006, October 2006 and October 2010.	3

7.4 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 7.2. Additional information on fish, macroinvertebrate and riparian vegetation reference conditions are also provided.

Table 7.2 OSAEH 11.6: Reference conditions

Comp	Reference conditions	Conf
Riparian vegetation	**Marginal zone:** Tree and shrub dominated state. More indigenous grass species and cover should be present, such as *Cynodon dactylon*, *Sporobolus africanus, Setaria sphacelata, Digitaria eriantha,* etc. Soil disturbance should not be present. Less terrestrial species should be present such as *Protasparagus laricinus*. Without impacts the response metrics would have been better on all accounts. **Non-marginal zone:** Grass dominated state (include sedges). With the absence of impacts more cover, abundance and better species composition would have occurred. Exotic species would be replaced by indigenous species such as *Pennisetum macrourum, Persicaria senegalensis, Cyperus eragrostis, Juncus effusus,* etc. Less water quality problems should occur, thus less vigorous growth of vegetation. Less erosion will ensure more habitats. Riparian vegetation species also expected under reference conditions include the following: *Setaria incrassata, Setaria sphacelata, Sporobolus africanus, Pennisetum macrourum, Digitaria eriantha, Persicaria senegalensis, Veronica Anagallis-aquatica, Cyperus eragrostis, Juncus effusus, Gymnosporia buxifolia, Rhus buxifolia, Cyperus esculentus, Schoenoplectus corymbosus*.	3
Fish	Reference conditions for the site were based on the NRHP site, **C7RENO-R501B.** See Table 6.3 for a list of the reference fish species.	4
Inverts	Reference conditions are based on professional judegement and Rivers Database information. The reference South African Scoring System version 5 (SASS5) score is 220 and the Average Score Per Taxon (ASPT) is 7.0.	3

7.4.1 Fish

Reference conditions broadly refer to “expectations on the state of aquatic biological communities in the absence of human disturbance and pollution”. In the context of this report, it refers specifically to the fish species present in a particular river reach and their frequency of occurrence under reference habitat conditions. Reference conditions for the site were largely based on the NRHP site, C7RENO-R501B (Kleynhans *et al.,* 2007b), downstream of the sampling site. Although the national RHP sites refer to a specific site, it is representative of the lower reaches of the Rhenosterspruit.

Based on the available information and professional judgement the following alterations were made for the purpose of this site:

- *Barbus paludinosus and Barbus trimaculatus* were included in the expected list. *Barbus paludinosus* was present at the site during recent site visit and is present in other adjacent tributaries.

Ten indigenous fish species are expected under reference conditions and are listed in Table 7.3.

Table 7.3 OSAEH 11.6: Reference fish species

Expected Reference and Habitat derived FROC of fish at OSAEH 11.6 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Austroglanis sclateri	Rock catfish	ASCL	3	1
Barbus paludinosus	Straightfin barb	BPAU	3	3
Barbus trimaculatus	Threespot barb	BTRI	3	1
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Labeo capensis	Orange River labeo	LCAP	5	5
Labeo umbratus	Moggel	LUMB	3	1

Expected Reference and Habitat derived FROC of fish at OSAEH 11.6 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Labeobarbus aeneus	Smallmouth yellowfish	BAEN	4	4
Labeobarbus kimberleyensis	Largemouth yellowfish	BKIM	3	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	4
Tilapia sparrmanii	Banded tilapia	TSPA	3	1
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%) 3 = present at about >25 - 50 % of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)				
ALIEN AND INVASIVE SPECIES				
Ctenopharyngodon idella	Grass Carp	CIDE		
Cyprinus carpio	Common Carp	CCAR		
Gambusia affinus	Mosquito fish	GAFF		
Micropterus salmoides	Largemouth bass	MSAL		

7.4.2 Macroinvertebrates

Macroinvertebrate taxa expected under reference conditions include:
Perlidae, Hydropsychidae (>2 spp.), Heptageniidae, Baetidae (>2 spp.), Tricorythidae, Elmidae/Dryopidae, Atyidae, Leptophlebiidae, Hydracarina, Simuliidae, Coenagrionidae, Naucoridae, Hydroptilidae, Tipulidae, Corbiculidae, Caenidae, Gerridae, Veliidae/ M...veliidae, Dytiscidae/Noteridae, Gyrinidae, Ceratopogonidae, Porifera, Hydrophilidae, Turbellaria, Potamonautidae, Corixidae, Chironomidae, Sphaeriidae, Oligochaeta, and Hirudinea.

7.5 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information provided with this report.

7.5.1 Index of Habitat Integrity (IIHI: C EC, 62.4%; RIHI: C EC, 73.4%)

The IIHI was rated a D (62.4%). This is mostly due to changes in water quality as a result of extensive cultivation and farming. The hydrology has probably changed due to reduced roughness in the catchment. The RIHI is a C/D (73.4%) with the main impacts being riparian encroachment due to increased nutrients and increased flow peaks from extensive hardened as well as the presence of exotic vegetation.

7.5.2 Diatoms (C EC)

The diatom community indicated that the biological water quality at the site was moderate (C EC) with a SPI score of 9.6. Elevated concentrations of organically bound nitrogen were present, with moderate saturated oxygen levels. Although organic pollution is moderate this site is strongly polluted.

7.5.3 Fish (C EC, 65.5%)

Three of the ten expected fish species were collected within this RU during the present survey suggesting that the FROC of some species have been reduced from reference conditions and that the site did not provide suitable habitat for the larger fish species. Based on their abundance, the FROC of smaller species such as *Barbus paludinosus* and *Pseudocrenilabrus philander* at this site was rated to be close to reference and can be contributed to plentiful marginal vegetation and slightly turbid waters, providing suitable cover. Although *T. sparrmanii, L. capensis L. umbratus, L. aeneus and L. kimberleyensis* was not collected at this site during the present survey, it is probable that these species are still present in the system where suitable habitat is available.

7.5.4 Macroinvertebrates (C EC, 70.6%)

Macroinvertebrates were sampled using the standard SASS5 method. Habitats sampled include Stones In Current (SIC), Stones Out of Current (SOOC), Marginal Vegetation Out of Current (MVOOC) and Sand and Mud (SM). For list of families present in the sample please refer to the MIRAI.

SASS results:

May 2006:	SASS5 score: 55	No of Taxa: 14	ASPT: 3.9
October 2006:	SASS5 score: 144	No of Taxa: 30	ASPT: 4.8
October 2010:	SASS5 score: 127	No of Taxa: 27	ASPT: 4.7

Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Perlidae and Heptageniidae. Notonectidae, Pleidae and Belostomatidae were more abundant than expected, while Elmidae, Caenidae, Coenagrionidae and Libellulidae were less abundant than expected. Those taxa which have a preference for very fast flowing water (>0.6m/s) were notably absent, namely Perlidae, Psephenidae, Hydropsychidae >2spp., Tricorythidae and Philopatamidae. Some taxa with a preference for moderately fast flowing water (0.3 – 0.6 m/s) were also absent, including Heptageniidae, Leptoceridae and Naucoridae.

7.5.5 Riparian vegetation (C EC, 71.1%)

The assessment was done using VEGRAI level 3. This site occurs within the Central Free State Grassland vegetation type, which has a vulnerable conservation status. Only small portions enjoy statutory conservation as well as some protection in private nature reserves.

Marginal Zone:
This zone is dominated by grass and sedges. The active channel is wide with the occurrence of braided bars forming a complex system of diverging and converging thalweg channels. Some of these channels contain water while others have little to no flow. Vegetation cover is good with little to no bare patches. Many sedge clumps occur in the channels. Some *Salix* trees infringe into this zone. Impacts consist mainly of erosion (bank slumping) and livestock footpaths. Exotic pioneers also occur. Indication of enrichment of water contributes to possible excessive growth of vegetation.

Non-marginal zone:
This zone is dominated by trees and shrubs. The riparian zone is narrow with steep banks. Impacts consist mainly of exotic and terrestrial vegetation (trees) encroachment, local fire regime, erosion in the form of banks that collapse and footpaths (livestock). Evidence of localised soil removal on the RHB occurred that can be the result of possible recent diamond mining. Exotic trees occur (*Gleditsia, Eucalyptus* and *Salix* sp.) that also contribute towards less undergrowth. However, vegetation cover is still good. Bank substrate consists mainly out of rocks and alluvial material.

7.5.6 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 7.4.

Table 7.4 OSAEH 11.6: Causes and sources

	PES	Causes	Sources	F/NF
Rip veg	C	Terrestrialisation.	Burning regime out of control. Annual burns enhance the encroachment of terrestrial species into the riparian zone.	NF
		Exotic invasion.	*Salix babylonica, Gleditsia triacanthos,* and *Eucalyptus* sp., and non-woody weeds.	
		Water quality.	Chicken farms, non-point source pollution (cultivation).	F
Fish	C	Loss of habitat diversity as a result of changes in hydrology.	Decreased flow in dry season and increased flood peaks.	F
		Decreased water quality affect species with requirement for high water quality.	Increased nutrients, sediments and toxins from agricultural areas.	NF
		Increased turbidity and disturbed bottom substrates.	Erosion and presence of bottom feeding alien (*C. carpio*).	
Inverts	C	Low flow conditions.	Abstraction - agriculture.	F
		Water quality and associated benthic growth.	Agriculture	NF

7.6 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 7.5.

Table 7.5 OSAEH 11.6: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Rip veg	C	Stable			The presence of the road crossing and old cement bridge will always have an impact on the habitat availability and integrity of this site. Footpath crossings, local burning regime and the presence of exotic vegetation species impact on the vegetation composition, cover and abundance. If these impacts can be managed the current situation can change and affect the current EC.	3
Fish	C	Stable			No other or new influences was identified that would cause a direction change in the Present Ecological State of the fish assemblage.	3
Inverts	C	Stable			The macroinvertebrates have already reacted to the current conditions.	3

7.7 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 7.6. The Instream EC is a C (68.1%).

Table 7.6 OSAEH 11.6: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	2.5	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	2	90		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	2	90		

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	1	80		
FISH ECOLOGICAL CATEGORY	7.5	360	**65.5**	**C**
MACROINVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	2.5	90		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	3	100		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	70		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**7.5**	260	**70.6**	**C**
INSTREAM ECOLOGICAL CATEGORY (Excl confidence)		620	**68.8**	**C**

INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	Confidence rating	Proportions	Modified weights
Confidence rating for **fish** information	3	0.50	32.75
Confidence rating for **macroinvertebrate** information	3	0.50	35.30
	6	1.00	68.05
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**C**

To determine the EcoStatus, the VEGRAI EC and confidence is included in the EcoStatus assessment index (Table 7.7). The EcoStatus EC is a C.

Table 7.7 OSAEH 11.6: Instream EC

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**71.1**	**C**	
ECOSTATUS	Confidence rating	Proportions	Modified weights
Confidence rating for instream biological information	3	0.45	30.93
Confidence rating for riparian vegetation zone information	3.6	0.55	38.78
	6.6	1.00	69.71
ECOSTATUS	**EC**		**C**

7.8 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised in Table 7.8.

Table 7.8 OSAEH 11.6: EcoClassification results

Driver Components	PES	Trend
IHI: INSTREAM	D	
IHI: RIPARIAN	C/D	
DIATOMS (WQ)	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	C	Stable
ECOSTATUS	C	

7.9 SUITABILITY AS FUTURE MONITORING SITE

7.9.1 Biotopes present

Good habitat diversity is available at the site for SASS sampling, if suitable flow is present. Excellent quality and quantity of marginal vegetation is present, with good quantity of cobble biotope and sand and mud biotopes present. Few localized impacts are present. Dense benthic algal growth is present due to nutrient enrichment. The site is easily accessible with wadeable areas. There is an abundance of undercut banks and marginal and/or overhanging vegetation present, which provide suitable habitat for small fish species. The marginal riparian zones present relatively good vegetation cover. Clear hydro-geomorphogical zones are present. Very little erosion is present. Exotic species are present in the riparian zone. Localised impacts are also present in the riparian zone.

Component	Advantages	Disadvantages	Conf
Rip veg	Easily accessible Marginal zones with relatively good vegetation cover Clear hydro-geomorphological zones Little erosion	Exotic species Water quality Veld burning regime Localised impacts Terrestrialisation Accessibility in the form of permission from land owner can be a problem	3
Fish	Easily accessible with wadeable areas. Abundance of undercut banks and marginal and/or overhanging vegetation provided suitable habitat for small species.	Low diversity of flow velocities and substratum provided limited cover for all species.	4
Inverts	Good quantity of cobble biotope present Diversity of velocities present Diversity of instream habitats present	Limited GSM biotope present Limited diversity of marginal vegetation present, mainly sedges Site situated immediately downstream of a gauging weir	3

7.9.2 Site suitability

The site suitability of each site was assessed and is provided in Table 7.9. All scores are out of 5 with 5 referring to very high suitability (see below).

Very High: 4.1 – 5 High: 3.1 – 4
Moderate: 2.1 – 3 Low: 1.1 – 2
Very Low: 0 – 1

Table 7.9 OSAEH 11.6: Biophysical site suitability

Site	Rip veg	Fish	Inverts	Average	Median	Max	Min	Comments
OSAEH 11.6	3	2	1	2	2	3	1	**Low** suitability for biotic component monitoring. Low diversity of flow velocities, and algal growth is problematic. This site is however ideal for riparian zone monitoring. Several hydro-geomorphological zones occur. Good species composition occurs. Although some impacts are present, this site can still reflect the overall condition of riparian zones in the area. Site accessibility is a problem due landowners providing permission for access.

8 OSAEH 11.4: SCHOONSPRUIT

8.1 SITE DESCRIPTION

Location	Schoonspruit	**Altitude**	1291 m
Longitude	26.6653	**Latitude**	-26.9333
EcoRegion	Highveld 11.01	**Quaternary catchment**	C24H
Water Management Area	Middle Vaal	**Geomorphological zone**	Lowland River

The sampling site is situated in the Schoonspruit approximately 10 km upstream of its confluence with the Vaal River. This site is located close to a township area, industrial area, and a small farm-house and downstream of gold mine activities. The site starts upstream of a roadbridge (± 25 m) and extends for ± 150 m to a brick building opposite a riffle area adjacent to a large *Salix babylonica* tree and is approximately 15 m wide. The substratum at the site was covered with benthic algae indicating the presence of excessive nutrients entering the system. The marginal vegetation is very well developed as a result of the available nutrients. Watercress (*Rorippa nasturtium-aquaticum*) was abundant, indicating excessive nutrients entering the system. Due to the dense algal mats present on the cobbles, macroinvertebrate colonization of this substrate is restricted. There was abundant, diverse marginal vegetation present. GSM and SOOC biotopes were also present.

Figure 8.1 Riffle section at OSAEH 11.4

Figure 8.2 Dense algal growth on the substratum

8.2 BIOTIC SAMPLING

8.2.1 Fish

The fish sampling was conducted at the site during October 2010. A river stretch of approximately a 100 m long, representing mostly slow shallow depth classes, was sampled for fish as the flow was low at the site resulting in scarce fast shallow and fast deep habitat. Four depth classes were sampled for 40 minutes in this stretch of river. Sampling and data analysis was followed according to Kleynhans (2007). A summary of the site conditions during sampling is provided below. Abundance of habitat was rated as:

- 0 = absent 1 = rare
- 2 = sparse 3 = moderate
- 4 = abundant 5 = very abundant

Fish velocity-depth classes and cover present at the site

SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
1	4	1	1
Overhanging vegetation			
1	1	1	1
Undercut banks and root wads			
0	0	0	0
Substrate			
0	3	1	1
Aquatic macrophytes			
0	0	0	0
Water Column			
1	0	0	0

Habitats sampled and effort

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Electro shocker (min)	5 min	20 min	5 min	10 min

8.3 DATA AVAILABILITY

Detailed information regarding available data is provided in Table 8.1.

Table 8.1 OSAEH 11.4: Summary of data availability

Comp	Data availability	Conf
IHI	Google Earth imagery. Information from Middle Vaal reserve study.	3
Riparian vegetation	Google Earth imagery. Data collected from field assessment during October 2010. Literature: **Kleynhans C.J, MacKenzie J., Louw M.D.** 2007a. Module F: Riparian Vegetation Response Assessment Index in River Classification: Manual for EcoStatus Determination (version 2). Joint Water Commission and Department of Water Affairs and Forestry report. WRC Report No. TT333/08. **Low B.A., Rebello A.G.** (eds) 1998. Vegetation of South Africa, Lesotho and Swaziland**.** Department of Environmental Affairs and Tourism, Pretoria. **Mucina L. & Rutherford M.C**. (eds) 2005. VEGMAP. Wall Map South African National Biodiversity Institute, Pretoria. **Mucina L. & Rutherford M.C.** (eds) 2006. Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19*. South African National Biodiversity Institute, Pretoria. **Van Wyk B. & Van Wyk P**. 2009. Field Guide to trees of Southern Africa. 12th Impression. Struik Nature Publishers, Cape Town.	3

Fish	One site visit and fish sampling during October 2010. South African Institute of Aquatic Biodiversity (SAIAB) data base (2006). **Kleynhans, C.J., Louw, M.D & Moolman, J**. 2007b. Module D (Volume 2): Reference Frequency of Occurrence of Fish Species in South Africa: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry Report. WRC Report No. TT330/08. Water Research Commission, Pretoria, South Africa.	3
Inverts	SASS5 surveys undertaken to determine the PES (Rivers Database) during November 2007 and October 2010.	2

8.4 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 8.2. Additional information on fish, macroinvertebrate and riparian vegetation reference conditions are also provided.

Table 8.2 OSAEH 11.4: Reference conditions

Comp	Reference conditions	Conf
Riparian vegetation	**Marginal zone:** *Phragmites australis* and grass dominated state (include sedges). Due to the availability of habitat (depicted by the rocky substrate) not much change is expected with regards to cover, abundance and better species composition. Exotic vegetation would be replaced by indigenous species such as *Pennisetum macrourum, Persicaria senegalensis, Cyperus eragrostis, Juncus effusus*. Less water quality problems should occur, this will result in less vigorous growth of vegetation. Less *Typha capensis* and *Phragmites australis* dominance would also be expected. **Non-marginal zone:** Grass and shrub dominated state. More indigenous grass species and cover should be present, such as *Cynodon dactylon*, *Sporobolus africanus, Setaria sphacelata, Digitaria eriantha,* etc. Less terrestrial species should be present such as *Protasparagus laricinus*. Without impacts the response metrics would have been better on all accounts. Less impact on water quality can be expected. Riparian vegetation species also expected under reference conditions include the following: *Setaria incrassata, Setaria sphacelata, Sporobolus africanus, Pennisetum macrourum, Digitaria eriantha, Persicaria senegalensis, Veronica Anagallis-aquatica, Cyperus eragrostis, Juncus effusus, Gymnosporia buxifolia, Rhus buxifolia, Cyperus esculentus, Schoenoplectus corymbosus*.	3
Fish	Reference conditions for the site were based on the NRHP site, **C2YSTE-ORKNE.** See Table 7.3 for a list of the reference fish species.	4
Inverts	Reference conditions are based on professional judgement and Rivers Database information. The reference South African Scoring System version 5 (SASS5) score is 230 and the Average Score Per Taxon (ASPT) is 6.5.	3

8.4.1 Fish

Reference conditions broadly refer to “expectations on the state of aquatic biological communities in the absence of human disturbance and pollution”. In the context of this report, it refers specifically to the fish species present in a particular river reach and their frequency of occurrence under reference habitat conditions. Although the national RHP sites refer to a specific site, it is representative of the lower reaches of the Schoonspruit. Based on the available information and professional judgement the following alterations were made for the purpose of this site:

- *Barbus anoplus, Barbus paludinosus and Barbus trimaculatus* were included in the expected list. *Barbus trimaculatus* was present at the site during recent site visit. These species are commonly found in the Mooi River (adjacent catchment).

Ten indigenous fish species are expected under reference conditions and are listed in Table 8.3.

Table 8.3 OSAEH 11.4: Reference fish species

Expected Reference and Habitat derived FROC of fish at OSAEH 11.4 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Barbus anoplus	Chubbyhead barb	BANO	5	1
Barbus paludinosus	Straightfin barb	BPAU	4	1
Barbus trimaculatus	Threespot barb	BTRI	4	2
Clarias gariepinus	Sharptooth catfish	CGAR	4	4
Labeo capensis	Orange River labeo	LCAP	4	3
Labeo umbratus	Moggel	LUMB	2	1
Labeobarbus aeneus	Smallmouth yellowfish	BAEN	4	1
Labeobarbus kimberleyensis	Largemouth yellowfish	BKIM	3	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	3	1
Tilapia sparrmanii	Banded tilapia	TSPA	3	1
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%) 3 = present at about >25 - 50 % of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)				
ALIEN AND INVASIVE SPECIES				
Cyprinus carpio	Common Carp	CCAR		
Gambusia affinus	Mosquito fish	GAFF		
Micropterus salmoides	Largemouth bass	MSAL		

8.4.2 Macroinvertebrates

Macroinvertebrate taxa expected under reference conditions include:
Perlidae, Hydropsychidae (>2 spp.), Heptageniidae, Baetidae (>2 spp.), Tricorythidae, Elmidae/Dryopidae, Atyidae, Leptophlebiidae, Hydracarina, Simuliidae, Coenagrionidae, Naucoridae, Ecnomidae, Philopotamidae, Hydroptilidae, Tipulidae, Corbiculidae, Caenidae, Gerridae, Veliidae, Dytiscidae, Gyrinidae, Psephenidae, Ceratopogonidae, Porifera, Hydrophilidae, Turbellaria, Potamonautidae, Corixidae, Chironomidae, Sphaeriidae, Oligochaeta, and Hirudinea.

8.5 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information provided with this report.

8.5.1 Index of Habitat Integrity (IHI: EC, 55.3%; RIHI: C EC, 61.3%)

The IHI was rated a D (59.5%). This is mostly due to changes in water quality as a result of extensive urban and mining runoff as well as cultivation. The hydrology has probably changed significantly due urban runoff and hardened surfaces. The RIHI is a C/D (61.3%) with the main impacts being increased flow peaks from extensive hardened, the presence of exotic vegetation and riparian encroachment due to increased nutrients.

8.5.2 Diatoms (D/E EC)

The biological water quality at this site was poor with a SPI score of 4.9. This relates to a EC of a D/E. Oxygen saturation was low, and organically bound nitrogen levels were continuously elevated indicating that nutrient loading is problematic at this site. Organic pollution levels were elevated indicating that organics may be problematic at times.

8.5.3 Fish (C EC, 64.5%)

Four of the ten expected fish species were collected within this RU during the present survey suggesting that the FROC of some species have been reduced from reference conditions. Based

on their abundance, the FROC of smaller species such as *B. trimaculatus*, *B. paludinosus* and *Pseudocrenilabrus philander* at this site was rated to be close to reference and can be contributed to plentiful marginal vegetation and slightly turbid waters, providing suitable cover. Although *T sparrmanii, L umbratus and L. kimberleyensis* was not collected at this site during the present survey, it is probable that these species are still present at the site.

8.5.4 Macroinvertebrates (C EC, 67.8%)

Macroinvertebrates were sampled using the standard SASS5 method. Habitats sampled include Stone In Current (SIC), Stones Out of Current (SOOC), Gravel, Sand and Mud (GSM), Marginal Vegetation In Current (MVIC) as well as bedrock and boulders. For list of families present in the sample please refer to the MIRAI.

SASS results:

Nov 2007:	SASS5 score: 164	No of Taxa: 33	ASPT: 5.0
Oct 2010:	SASS5 score: 47	No of Taxa: 13	ASPT: 3.6

Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Perlidae, Hydropsychidae >2spp. and Heptageniidae. Hirudinea, Dytiscidae, Planorbinae, and Oligochaeta were more abundant than expected, while Nepidae and Coenagrionidae were less abundant than expected.

8.5.5 Riparian vegetation (C EC, 68.3%)

The assessment was done using VEGRAI level 3. This site occurs within the Vaal-Vet Sandy Grassland vegetation type, which has an endangered conservation status and only 0.3% protected.

Marginal Zone:

The current vegetation dominating the area is grass (mainly sedges) and some reed clumps (more so on the RB). Little to no bare patches occur. Rocky substrate dominates the area. Exotic pioneer species occur such as *Persicaria lapathifolia, Ranunculus multifidus, Argemone mexicana, Cirsium vulgare*. The hydrophyte *Nasturtium officinale* occurs in the open water areas with clumps of *Phragmites australis* and *Typha capensis*. Some *Salix babylonica* trees infringe into the marginal zone. Impacts consist mainly of rubbish dumping and exotic vegetation. However, good indigenous vegetation cover and abundance occur. Indication of enrichment of water can contribute to excessive growth of vegetation.

Non-marginal zone:

Grass and shrub dominated state. Impacts consist mainly of exotic and terrestrial vegetation, fire and footpaths. These impacts are due to human activity and the trampling by livestock. Exotic trees occur (*Gleditsia, Eucalyptus* and *Salix* sp.) and contribute towards less undergrowth. This zone is also dominated by *Protasparagus laricinus*. Bank substrate consists mainly of rocks.

8.5.6 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 8.4.

Table 8.4 OSAEH 11.4: Causes and sources

	PES	Causes	Sources	F/NF
Rip veg	C	Terrestrialisation.	Burning regime out of control. Annual burns enhance the encroachment of terrestrial species into the riparian zone.	NF
		Exotic invasion.	*Salix babylonica, Gleditsia triacanthos,* and *Eucalyptus* sp., and non-woody weeds.	
		Water quality.	Mining, chicken farms, non-point pollution, etc.	F
Fish	C	Loss of habitat diversity as a result of flow modification.	Inundation upstream and flow modification.	F
		Decreased water quality affect species with requirement for high water quality.	Increased nutrients, sediments and toxins from urban areas diamond and gold mines and agricultural areas.	NF
		Increased turbidity and disturbed bottom substrates.	Erosion and presence of bottom feeding alien (*C. carpio*).	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Major upstream and downstream dams as well as weirs.	
Inverts	C	Flow modification.	Agriculture.	F
		Water quality and associated benthic growth.	Agriculture, settlements and urbanization.	NF

8.6 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 8.5.

Table 8.5 OSAEH 11.4: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Rip veg	C	Stable			A burning regime that is out of control on an annual basis impact on the vegetation composition, cover and abundance, especially in the non-marginal zone. The riparian vegetation has responded and it is improbable that current situation will change remarkably so as to affect the current EC.	3
Fish	C	Stable			No other or new influences was identified that would cause a direction change in the Present Ecological State of the fish assemblage.	3
Inverts	C	Stable			The macroinvertebrates have already reacted to the current conditions.	3

8.7 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 8.6. The Instream EC is a C (65.8%).

Table 8.6 OSAEH 11.4: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	2.5	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	2	90		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	2	90		

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	1	80		
FISH ECOLOGICAL CATEGORY	7.5	360	**64.5**	**C**
MACROINVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	3	100		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	2.5	90		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	70		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**7.5**	260	**67.8**	**C**
INSTREAM ECOLOGICAL CATEGORY (Excl confidence)		620	**66.6**	**C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	3	0.60	38.70	
Confidence rating for **macroinvertebrate** information	2	0.40	27.12	
	5	1.00	65.82	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**C**	

To determine the EcoStatus, the Vegetation Response Assessment Index (VEGRAI) EC and confidence is included in the EcoStatus assessment index (Table 8.7). The EcoStatus EC is a C.

Table 8.7 OSAEH 11.4: Instream EC

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**68.3**	**C**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	2.6	0.42	27.60
Confidence rating for riparian vegetation zone information	3.6	0.58	39.66
	6.2	1.00	67.26
ECOSTATUS	**EC**		**C**

8.8 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised in Table 8.8.

Table 8.8 OSAEH 11.4: EcoClassification results

Driver Components	PES	Trend
IHI: INSTREAM	D	
IHI: RIPARIAN	C/D	
DIATOMS (WQ)	D/E	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	C	Stable
ECOSTATUS	C	

8.9 SUITABILITY AS FUTURE MONITORING SITE

8.9.1 Biotopes present

Habitat diversity is fair with a good quantity of cobbles present. However due to the dense benthic algal growth, macroinvertebrate colonization is restricted. Good quantity and quality of marginal vegetation is available for sampling. The site is easily accessible with wadeable areas. An abundance of undercut banks and marginal and/or overhanging vegetation provides suitable habitat for small fish species. The substratum is slightly embedded with sediments. A low diversity of flow velocities is present and is dominated by a slow shallow habitat for fish species. The marginal riparian zone has relatively good vegetation cover, with good species diversity. No erosion is present at the site. Exotic riparian vegetation species are present within the narrow riparian zone. A negative to this site is that the riparian zone is very narrow and the vegetation occurrence is defined by its rocky substrate. Besides this, this site can still reflect the overall condition of riparian zones in the area. However, it is advised that the availability of other sites should be investigated.

Component	Advantages	Disadvantages	Conf
Rip veg	Easily accessible (RB) Marginal zones with relative good vegetation cover Good species diversity No erosion	Exotic species Water quality Veld burning regime Localised impacts (infrastructure, dumping, etc.) Terrestrialisation Narrow riparian zone Rocky substrates define habitat availability	3
Fish	Easily accessible with wadeable areas. Abundance of undercut banks and marginal and/or overhanging vegetation provided suitable habitat for small species	Substratum slightly embedded with sediments Prominence of benthic algae Low diversity of flow velocities dominated by slow shallow Substratum blanketed by algae reducing cover for all species	4

Inverts	Good quantity of cobble biotope present Diversity of instream habitats present Good quality and quantity of marginal vegetation	Dense benthic algal growth creating very poor quality of cobble biotope Localised impacts include land-use (agriculture and settlements in the immediate area)	3

8.9.2 Site suitability

The site suitability of each site was assessed and is provided in Table 8.9. All scores are out of 5 with 5 referring to very high suitability (see below).

Very High: 4.1 – 5 High: 3.1 – 4
Moderate: 2.1 – 3 Low: 1.1 – 2
Very Low: 0 – 1

Table 8.9 OSAEH 11.4: Biophysical site suitability

Site	Rip veg	Fish	Inverts	Average	Median	Max	Min	Comments
OSAEH 11.4	2	2	2	2	2	2	2	**Low** suitability for biotic component monitoring. Low diversity of flow velocities, and algal growth is problematic. The riparian zone is very narrow and the vegetation occurrence is defined by its rocky substrate.

9 OSAEH 11.1: WOLWESPRUIT

From Google imagery it was determined that the originally proposed site had limited instream habitat available for sampling purposes, hence the Wolwespruit site was selected as an appropriate monitoring site for this project. This new site in the Wolwespruit Nature Reserve provides unique/different habitat types when compared to the originally proposed site. Furthermore, the land use impact within the Nature Reserve is less than outside the Reserve which is that of agricultural use.

9.1 SITE DESCRIPTION

Location	Wolwespruit Nature Reserve	**Altitude**	1242 m
Longitude	26°19'48.1"	**Latitude**	27°24'06.2"
EcoRegion	Highveld 11.08	**Quaternary catchment**	C24J
Water Management Area	Middle Vaal	**Geomorphological zone**	Lowland River

This site is situated downstream of a picnic site in the Wolwespruit Nature Reserve, on the Vaal River main stem. The sampling site is situated approximately 128 km upstream of Bloemhof Dam and the river is approximately 100 m wide with small, vegetated islands which provide diverse marginal vegetation. It extends from adjacent a riffle and an island along a sandy bar downstream to an open sandy patch next to a steep river bank on the right (±180 m). The site has extensive cobble beds for sampling purposes; however dense benthic algal growth is present on the cobbles. There is a good diversity of instream habitats present. The river channel is scoured locally as a result of upstream impoundments. The riparian slope is reasonably steep from the edge to the water.

Conservation is present on the RB and farming activities occur in and adjacent to the site on the LB. Some bank slumping has resulted in small islands occurring adjacent to the edge of the bank. The substrate of the riparian zone consists mainly of sandy alluvial material and it is thus expected that habitat change will take place in this dynamic environment. Some trampling and footpaths are visible.

Figure 9.1 Extensive runs over mainly cobble substrate

9.2 BIOTIC SAMPLING

9.2.1 Fish

The fish sampling was conducted at the site during October 2010. A river stretch of approximately a 100 m long, representing a variety of depth classes, was sampled although SD habitat was rare due to strong flow on the day of sampling. Four depth classes were sampled for 80 minutes in this stretch of river. Sampling and data analysis was followed according to Kleynhans (2007). A summary of the site conditions during sampling is provided below. Abundance of habitat was rated as:

- 0 = absent
- 1 = rare
- 2 = sparse
- 3 = moderate
- 4 = abundant
- 5 = very abundant

Fish velocity-depth classes and cover present at the site

SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
1	2	4	3
Overhanging vegetation			
0	1	0	0
Undercut banks and root wads			
0	0	0	0
Substrate			
0	2	4	3
Aquatic macrophytes			
1	0	0	0
Water Column			
0	0	0	0

Habitats sampled and effort

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Electro shocker (min)		20 min	45 min	15 min

9.3 DATA AVAILABILITY

Detailed information regarding available data is provided in Table 9.1.

Table 9.1 OSAEH 8.1: Summary of data availability

Comp	Data availability	Conf
IHI	Google Earth imagery. Information from Middle Vaal reserve study.	3
Riparian vegetation	Google Earth imagery. Data collected from field assessment during October 2010. Literature: **Kleynhans C.J, MacKenzie J., Louw M.D.** 2007a. Module F: Riparian Vegetation Response Assessment Index in River Classification: Manual for EcoStatus Determination (version 2). Joint Water Commission and Department of Water Affairs and Forestry report. WRC Report No. TT333/08. **Low B.A., Rebello A.G.** (eds) 1998. Vegetation of South Africa, Lesotho and Swaziland**.** Department of Environmental Affairs and Tourism, Pretoria. **Mucina L. & Rutherford M.C**. (eds) 2005. VEGMAP. Wall Map South African National Biodiversity Institute, Pretoria. **Mucina L. & Rutherford M.C.** (eds) 2006. Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19*. South African National Biodiversity Institute, Pretoria. **Van Wyk B. & Van Wyk P**. 2009. Field Guide to trees of Southern Africa. 12th Impression. Struik Nature Publishers, Cape Town.	3

Fish	One site visit and fish sampling during October 2010. South African Institute of Aquatic Biodiversity (SAIAB) data base (2006). **Kleynhans, C.J., Louw, M.D & Moolman, J**. 2007b. Module D (Volume 2): Reference Frequency of Occurrence of Fish Species in South Africa: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry Report. WRC Report No. TT330/08. Water Research Commission, Pretoria, South Africa.	3
Inverts	SASS5 surveys undertaken to determine the PES (Rivers Database) during May 2006, October 2006 and October 2010.	3

9.4 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 9.2. Additional information on fish, macroinvertebrate and riparian vegetation reference conditions are also provided.

Table 9.2 OSAEH 11.1: Reference conditions

Comp	Reference conditions	Conf
Riparian vegetation	**Marginal zone:** Reed and grass dominated state (include sedges). With the absence of impacts more cover, abundance and better species composition would have occurred. More indigenous species such as *Setaria incrassata, Sporobolus africanus, Pennisetum macrourum, Persicaria senegalensis, Veronica anagallis-aquatica, Cyperus eragrostis, Juncus effusus,* can occur. Exotic pioneers would be replaced by indigenous pioneers. Sand/alluvial material will still be in place and more stability is expected. Less erosion in the form of bank undercutting would be present. **Non-marginal zone:** Tree and shrub dominated state. More indigenous grass cover should be present, such as *Cynodon dactylon*, *Sporobolus africanus, Setaria sphacelata, Digitaria eriantha*. Without the impacts of and/or better management of exotic species, activity of local fishermen and game/cattle the response metrics would have been better on all accounts. Less impact on water quality can be expected. While in this dynamic state the river bank should be more stable. Riparian vegetation species also expected under reference conditions include the following: *Setaria incrassata, Setaria sphacelata Sporobolus africanus, Pennisetum macrourum, Digitaria eriantha, Persicaria senegalensis, Veronica Anagallis-aquatica, Cyperus eragrostis, Juncus effusus, Gymnosporia buxifolia, Rhus buxifolia, Cyperus esculentus, Schoenoplectus corymbosus*.	4
Fish	Reference conditions for the site were based on the NRHP site, C2VAAL-BLOEM. See Table 8.3 for a list of the reference fish species.	4
Inverts	Reference conditions are based on professional judgement and Rivers Database information. The reference South African Scoring System version 5 (SASS5) score is 220 and the Average Score Per Taxon (ASPT) is 7.	3

9.4.1 Fish

Reference conditions broadly refer to “expectations on the state of aquatic biological communities in the absence of human disturbance and pollution”. In the context of this report, it refers specifically to the fish species present in a particular river reach and their frequency of occurrence under reference habitat conditions. Reference conditions for the site were largely based on the NRHP site, C2VAAL-BLOEM (Kleynhans *et al.,* 2007b), downstream of the sampling site. Although the national RHP sites refer to a specific site, it is representative of the river reach downstream of Bloemhof Dam down to the Vaalharts Dam.

Based on the available information and professional judgement the following alterations were made for the purpose of this site:

- *Barbus anoplus* were omitted from the expected list as this species mainly occur in smaller tributaries of the Vaal River and are unlikely to occur in the main stem.
- *Barbus paludinosus and Barbus trimaculatus* were included in the expected list as these species were present at the site during recent site visit.

Ten indigenous fish species are expected under reference conditions and are listed in Table 9.3.

Table 9.3 OSAEH 11.1: Reference fish species

Expected Reference and Habitat derived FROC of fish at OSAEH 11.1 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Austroglanis sclateri	Rock catfish	ASCL	2	1
Barbus paludinosus	Straightfin barb	BPAU	5	3
Barbus trimaculatus	Threespot barb	BTRI	5	1
Clarias gariepinus	Sharptooth catfish	CGAR	3	3
Labeo capensis	Orange River labeo	LCAP	4	4
Labeo umbratus	Moggel	LUMB	3	2
Labeobarbus aeneus	Smallmouth yellowfish	BAEN	4	4
Labeobarbus kimberleyensis	Largemouth yellowfish	BKIM	2	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	3
Tilapia sparrmanii	Banded tilapia	TSPA	4	3
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%) 3 = present at about >25 - 50 % of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)				
ALIEN AND INVASIVE SPECIES				
Ctenopharyngodon idella	Grass Carp	CIDE		
Cyprinus carpio	Common Carp	CCAR		
Gambusia affinus	Mosquito fish	GAFF		
Micropterus salmoides	Largemouth bass	MSAL		

9.4.2 Macroinvertebrates

Macroinvertebrate taxa expected under reference conditions include:
Perlidae, Hydropsychidae (>2 spp.), Heptageniidae, Baetidae (>2 spp.), Tricorythidae, Elmidae/Dryopidae, Atyidae, Leptophlebiidae, Hydracarina, Simuliidae, Coenagrionidae, Naucoridae, Hydroptilidae, Tipulidae, Corbiculidae, Caenidae, Gerridae, Veliidae/ M...veliidae, Dytiscidae/Noteridae, Gyrinidae, Ceratopogonidae, Porifera, Hydrophilidae, Turbellaria, Potamonautidae, Corixidae, Chironomidae, Sphaeriidae, Oligochaeta, and Hirudinea.

9.5 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information provided with this report.

9.5.1 Index of Habitat Integrity (IHI: C EC, 59.5%; RIHI: C EC, 68.5%)

The IHI was rated as a C/D (59.5%). This is mostly due to changes in water quality as a result of extensive cultivation as well as urban and mining runoff in upstream tributaries. The hydrology has also changed significantly due to upstream inundation and flow modification. The RIHI is a C (68.5%) with the main impacts being substrate exposure due to extensive cultivation and diamond mining as well as the presence of exotic vegetation.

9.5.2 Diatoms (C EC)

The SPI score at this site was 11.7. The community indicated fairly high oxygen saturation with elevated levels of organically bound nitrogen. Organic pollution levels are low and overall the site is moderately polluted.

9.5.3 Fish (C EC, 64.5%)

Seven of the ten expected fish species were collected at this site during the recent survey within this Resource Unit (RU) suggesting that the FROC of some species have been reduced from

reference conditions. Alien and invasive species such as C*tenopharyngodon idella* and *Cyprinus carpio* and were notably abundant at the site. *Labeobarbus aneaus* were notably less abundanant than *Cyprinus carpio* at this site probably as a result of habitat deterioration (bethic algae and sedimentation). Based on their abundance, the FROC of smaller species such as *B. trimaculatus*, *B. paludinosus* and *Pseudocrenilabrus philander* at this site was rated to be close to reference and can be contributed to plentiful marginal vegetation and slightly turbid waters, providing suitable cover. Although *T sparrmanii, L umbratus and L. kimberleyensis* was not collected at this site during the present survey, it is probable that these species are still present at the site.

9.5.4 Macroinvertebrates (C EC, 65.9%)

Macroinvertebrates were sampled using the standard SASS5 method. Habitat sampled include Stones in Current (SIC), Marginal Vegetation In Current (MVIC), Gravel, Sand and Mud (GSM). For list of families present in the sample please refer to the MIRAI.

SASS results:

May 2006:	SASS5 score: 55	No of Taxa: 14	ASPT: 3.9
Oct 2006:	SASS5 score: 144	No of Taxa: 30	ASPT: 4.8
Oct 2010:	SASS5 score: 110	No of Taxa: 19	ASPT: 5.8

Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Perlidae and Heptageniidae. The dense algal growth has a negative impact on the instream habitat available for macroinvertebrate colonization and can be seen in the high rating for the cobble habitat (3.5). Taxa expected but not observed in this biotope include Aeshnidae, Ecnomidae, Libellulidae and Psephenidae. Tricorythidae were more abundant than expected, while Atyidae, Coenagrionidae and Hydrophilidae were less abundant than expected.

9.5.5 Riparian vegetation (C EC, 64.1%)

The assessment was done using VEGRAI level 3. This site occurs within the Highveld Alluvial vegetation type, which has a least threatened conservation status with nearly 10% protected. This site is located in the Wolwespruit Nature Reserve.

Marginal Zone:

The vegetation type dominating this site is grass (include sedges). Some *Phragmites australis* clumps occur, more so on the LB. Small, bare patches occur at this site. Impacts consist mainly of flooding, vegetation removal, exotic vegetation (mainly pioneers) and footpaths. The presence of footpaths is mainly because of recreational activity (fishermen) and the movement of livestock and game. Reasonable vegetation cover and abundance is present at this site. Exotic pioneers that dominate are *Ricinus communis*, *Pseudognaphalium luteo-album*, Pentzia *pilulifera*, *Nasturtium officinale*, among others. Some *Salix babylonica* trees are present. Other species that occur include *Cyperus esculentus*, *Peucedanum thodei*, and *Melilotus indica.* Some bank under-cutting occurs in the marginal zone (edge to the water level). Substrate consists of sand and alluvial material.

Non-marginal zone:

This site is dominated by trees and shrubs. Impacts consist mainly of exotic vegetation and footpaths (trampling). The trampling is due to recreation in the form of fishermen and trampling by game and livestock. Exotic trees that occur (*Gleditsia triacanthos* and *Salix babylonica*) contribute towards less undergrowth. Other indigenous species that dominate are *Acacia karroo, Ziziphus mucronata, Rhus pyroides, Gymnosporia buxifolia,* and *Diospyros lycioides,* among others. Some

patchy grass cover occurs (dominated by the exotic *Bromus catharticus*). The river bank does not appear to be very stable with evidence of slumping taking place.

9.5.6 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 9.4.

Table 9.4 OSAEH 11.1: Causes and sources

	PES	Causes	Sources	F/NF
Rip veg	C	Vegetation removal.	Trampling/grazing by game/cattle and some fishermen activity.	NF
		Exotic invasion.	*S. babylonica, G. triacanthos,* and *Eucalyptus* sp., and dominant non-woody weeds.	
		Bank undercutting and scouring	Substrate of site consists out of sand and alluvial material. Due to dynamics of aggradation and degradation habitat change is constant. Bank instability and the impact of trampling and exotic vegetation among others, contribute towards bank erosion.	F
Fish	C	Loss of habitat diversity as a result of flow modification.	Inundation upstream and flow modification.	F
		Decreased water quality affect species with requirement for high water quality.	Increased nutrients, sediments and toxins from urban areas diamond and gold mines and agricultural areas.	NF
		Increased turbidity and disturbed bottom substrates.	Erosion and presence of bottom feeding alien (*C. carpio*).	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Major upstream and downstream dams as well as weirs.	
Inverts	C	Loss of habitat diversity.	Inundation upstream and flow modification.	F
		Water quality and associated benthic growth of algae.	Agriculture, mining and urbanization.	NF

9.6 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 9.5.

Table 9.5 OSAEH 11.1: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Rip veg	C	Stable			The riparian vegetation has already responded to the dynamics of bank instability and it is improbable that fishermen activity, game/cattle activity will decrease and that alien vegetation cover will increase remarkably so as to affect the current EC.	3
Fish	C	Stable			The riparian vegetation has already responded to the dynamics of bank instability and it is improbable that fishermen activity, game/cattle activity will decrease and that alien vegetation cover will increase remarkably so as to affect the current EC.	3
Inverts	C	Stable			The macroinvertebrates have already reacted to the current conditions.	3

9.7 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 9.6. The Instream EC is a C (65.2%).

Table 9.6 OSAEH 11.1: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	2.5	90		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	2	80		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2	80		
FISH ECOLOGICAL CATEGORY	9.5	350	**64.5**	**C**
MACROINVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	3.5	100		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	3	90		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	70		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**8.5**	260	**65.9**	**C**
INSTREAM ECOLOGICAL CATEGORY (Excl confidence)		610	**65.4**	**C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	3	0.50	32.25	
Confidence rating for **macroinvertebrate** information	3	0.50	32.95	
	6	1.00	65.20	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**C**	

To determine the EcoStatus, the VEGRAI EC and confidence is included in the EcoStatus assessment index (Table 9.7). The EcoStatus EC is a C.

Table 9.7 OSAEH 11.1: Instream EC

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**64.1**	**C**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	3	0.45	29.64
Confidence rating for riparian vegetation zone information	3.6	0.55	34.96
	6.6	1.00	64.60
ECOSTATUS	**EC**		**C**

9.8 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised in Table 9.8.

Table 9.8 OSAEH 11.1: EcoClassification results

Driver Components	PES	Trend
IHI: INSTREAM	C/D	
IHI: RIPARIAN	C	
DIATOMS (WQ)	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	C	Stable
ECOSTATUS	C	

9.9 SUITABILITY AS FUTURE MONITORING SITE

9.9.1 Biotopes present

Good habitat diversity is available at the site for SASS sampling, including excellent quantity of cobble biotope, excellent quantity and quality of marginal vegetation, limited SOOC biotope available and good GSM biotope present. A fair diversity of velocities was present. The site has few localised impacts due to the fact that it is situated in the Wolwespruit Nature Reserve.

The site is easily accessible with wadeable areas. For fish sampling there is abundant fast, deep habitat available, providing good cover for larger species, as well as diverse substratum providing good cover for all fish species. An abundance of undercut banks and overhanging vegetation provides suitable habitat for small fish species. The substratum is slightly embedded with sediments. Access to the site is gained via entry into the Wolwespruit Nature Reserve. The site is easily accessible once in the Reserve. Future riparian vegetation monitoring on this site can be considered. A negative to this site is that the instability of the riparian zone due to the alluvial dynamics. However, this condition does reflect the condition of large areas in this river reach.

Component	Advantages	Disadvantages	Conf
Rip veg	Easily accessible (RB) Easy distinction between marginal and non-marginal zone Marginal zone with relatively good vegetation cover Nursery bars occur (act as propagule pool)	Dominate by exotic pioneers (mainly the marginal zone) Bank instability occurs (bank slumping and undercutting) Slope of non- marginal zone is steep Agricultural activities adjacent to the LHB Accessibility to the left hand bank	4
Fish	Easily accessible with wadeable areas. High diversity of flow velocities. Abundant Fast Deep provided suitable habitat for larger species Diversity of substratum provided good cover for all species. Abundance of undercut banks and marginal and/or	Substratum slightly embedded with sediments Prominence of benthic algae	4

Component	Advantages	Disadvantages	Conf
	overhanging vegetation provided suitable habitat for small species.		
Inverts	Excellent quantity of cobble biotope present Fair diversity of velocities present Few localised impacts Diversity of instream habitats present Excellent quality and quantity of marginal vegetation	Limited SOOC biotope present Dense benthic algal growth	3

9.9.2 Site suitability

The site suitability of each site was assessed and is provided in Table 9.9. All scores are out of 5 with 5 referring to very high suitability (see below).

Very High: 4.1 – 5 High: 3.1 – 4
Moderate: 2.1 – 3 Low: 1.1 – 2
Very Low: 0 – 1

Table 9.9 OSAEH 11.1: Biophysical site suitability

Site	Rip veg	Fish	Inverts	Average	Median	Max	Min	Comments
OSAEH 11.1	3	3	3	3.00	3	3	3	**Moderate** suitability for biotic component monitoring. Diversity of habitats present at site is scarce considering the reach. A negative to this site is that the instability of the riparian zone due to the alluvial dynamics.

10 EWR 16: DS OF BLOEMHOF DAM

EWR 16 was assessed as part of the Lower Vaal Reserve study, and the results are provided in the summary report (Technical report 1). The results provided below are based on the assessment undertaken during October 2010 as part of this study.

10.1 SITE DESCRIPTION

Location	EWR 16 DS of Bloemhof	**Altitude**	1211 m
Longitude	25.59564	**Latitude**	-27.65541
EcoRegion	Highveld/Southern Central Kalahari 11.08, 29.02	**Quaternary catchment**	C91A
Water Management Area	Lower Vaal	**Geomorphological zone**	Lower Foothills

EWR 16 is situated directly downstream of the C9H021 gauging weir and about 3 km downstream of Bloemhof Dam. The river channel was notably scoured locally as a result of the upstream impoundments. The substratum at the sampling site is dominated by large boulders and was free of sediments and algae. The river is approximately 100 m in width and the site is accessible. A fair diversity of instream habitat is available for sampling, with a diversity of velocities present. Biotopes sampled include Stones in Current (SIC), Stones Out Of Current (SOOC) and limited Marginal Vegetation Out of Current (MVOOC). Gravel, Sand and some Mud (GSM) was sampled.

Figure 10.1 EWR 16, October 2010

10.2 BIOTIC SAMPLING

10.2.1 Fish

The fish sampling was conducted at the site during October 2010. A river stretch of approximately a 100 m long, representing a variety of depth classes, was sampled although SD habitat was rare due to strong flow on the day of sampling. Four depth classes were sampled for 80 minutes in this stretch of river. Sampling and data analysis was followed according to Kleynhans *et al*. (2008). A summary of the site conditions during sampling is provided below. Abundance of habitat was rated as:

- 0 = absent
- 1 = rare
- 2 = sparse
- 3 = moderate
- 4 = abundant
- 5 = very abundant

Fish velocity-depth classes and cover present at the site

SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
1	2	4	3
Overhanging vegetation			
0	1	0	0
Undercut banks and root wads			
0	0	0	0
Substrate			
0	2	4	3
Aquatic macrophytes			
1	0	0	0
Water Column			
0	0	0	0

Habitats sampled and effort

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Electro shocker (min)		20 min	45 min	15 min

10.2.2 Riparian vegetation

Two sites were assessed at a level 3, to get a representative example of the riparian zones in the area. In some riparian areas the impacts are detrimental to the riparian zone integrity (Figure 10.2), but in other places impacts are present but not as severe.

The site on the RB (Figure 10.3) is located downstream of the road bridge (Bloemhof – Hertzogville). The site extent is from a water effluent point (from the golf course) to a rocky outcrop (±200 m) downstream. The slope of this riparian zone is reasonably steep from the riparian edge to the water. This site occurs adjacent to a Golf Course. Little vegetation cover occurs. This is a popular fishing spot for local fishermen.

Figure 10.2 Photo of site location on the right hand bank

Figure 10.3 Photo of site location on the left hand bank

10.3 DATA AVAILABILITY

Detailed information regarding available data is provided in Table 10.1.

Table 10.1 EWR 16: Summary of data availability

Comp	Data availability	Conf
IHI	Google Earth imagery. Information from Lower Vaal Reserve study.	3
Riparian vegetation	Google Earth imagery. Data collected from field assessment during October 2010. Literature: **Kleynhans C.J, MacKenzie J., Louw M.D.** 2007a. Module F: Riparian Vegetation Response Assessment Index in River Classification: Manual for EcoStatus Determination (version 2). Joint Water Commission and Department of Water Affairs and Forestry report. WRC Report No. TT333/08. **Low B.A., Rebello A.G.** (eds) 1998. Vegetation of South Africa, Lesotho and Swaziland**.** Department of Environmental Affairs and Tourism, Pretoria. **Mucina L. & Rutherford M.C**. (eds) 2005. VEGMAP. Wall Map South African National Biodiversity Institute, Pretoria. **Mucina L. & Rutherford M.C.** (eds) 2006. Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19*. South African National Biodiversity Institute, Pretoria. **Van Wyk B. & Van Wyk P**. 2009. Field Guide to trees of Southern Africa. 12th Impression. Struik Nature Publishers, Cape Town.	3
Fish	One site visit and fish sampling during October 2010. South African Institute of Aquatic Biodiversity (SAIAB) data base (2006). **Kleynhans, C.J., Louw, M.D & Moolman, J**. 2007b. Module D (Volume 2): Reference Frequency of Occurrence of Fish Species in South Africa: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry Report. WRC Report No. TT330/08. Water Research Commission, Pretoria, South Africa. Vaal River EWR sampling data.	3
Inverts	One SASS5 survey undertaken to determine the PES during October 2010 Report information used: Vaal River EWR sampling data.	2

10.4 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 10.2. Additional information on fish, macroinvertebrate and riparian vegetation reference conditions are also provided.

Table 10.2 EWR 16: Reference conditions

Comp	Reference conditions	Conf
Riparian vegetation	**Marginal zone:** Reed and grass dominated state (including sedges). With the absence of vegetation removal impacts (stock and fishermen) and the occurrence of exotic vegetation more cover, abundance and a better species composition should occur. Better cover by *Phragmites australis* and sedges such as *Cyperus denudatus*, *C. longus*, *Schoenoplectus* sp. etc. should occur. Sedge and some grass abundance would have been better. Grasses such as *Agrostis Lagenantha, Ischaemum fasciculatum, Sporobolus africana*, etc. This would have led to a better species composition. Less erosion in the form of bank undercutting can be expected. **Non-marginal zone:** Tree and shrub dominated state. More grass cover would be present. Without cattle, exotic species and activity of local fishermen the response metrics would have been better on all accounts. Less exotic species can make way for indigenous species such as *Ehretia rigida, Grewia flava, Celtis africana*, etc. Riparian vegetation species also expected under reference conditions include the following: *Ziziphus mucronata, Acacia karroo, Gymnosporia buxifolia, Diospyros lycioides, Rhus buxifolia, Cyperus esculentus, Schoenoplectus corymbosus, Imperata cylindrica*, etc.	3
Fish	Reference conditions for the site were based on the NRHP sites, C9VAAL-WARRE and C9VAAL-CHRIS. See Table 9.3 for a list of the reference fish species.	4
Inverts	Reference conditions are based on professional judgement and Rivers Database information. The reference South African Scoring System version 5 (SASS5) score is 200 and the Average Score Per Taxon (ASPT) is 6.5.	3

10.4.1 Fish

Reference conditions broadly refer to “expectations on the state of aquatic biological communities in the absence of human disturbance and pollution”. In the context of this report, it refers specifically to the fish species present in a particular river reach and their frequency of occurrence under reference habitat conditions. Reference conditions for the site were largely based on the NRHP site, C9VAAL-WARRE and C9VAAL-CHRIS (Kleynhans *et al*., 2007b), downstream of the sampling site. Although the national RHP sites refer to a specific site, it is representative of the river reach downstream of Bloemhof Dam down to the Vaalharts Dam.

Based on the available information and professional judgement the following alterations were made for the purpose of this site:

- *Barbus anoplus* were omitted from the expected list as this species mainly occur in smaller tributaries of the Vaal River and are unlikely to occur in the main stem.

Ten indigenous fish species are expected under reference conditions and are listed in Table 10.3.

Table 10.3 EWR 16: Reference fish species

Expected Reference and Habitat derived FROC of fish at EWR 16 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Austroglanis sclateri	Rock catfish	ASCL	2	1
Barbus paludinosus	Straightfin barb	BPAU	5	3
Barbus trimaculatus	Threespot barb	BTRI	5	1
Clarias gariepinus	Sharptooth catfish	CGAR	3	3
Labeo capensis	Orange River labeo	LCAP	4	4
Labeo umbratus	Moggel	LUMB	3	2
Labeobarbus aeneus	Smallmouth yellowfish	BAEN	4	4
Labeobarbus kimberleyensis	Largemouth yellowfish	BKIM	2	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	3
Tilapia sparrmanii	Banded tilapia	TSPA	4	3

Expected Reference and Habitat derived FROC of fish at EWR 16 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%) 3 = present at about >25 - 50 % of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)				
ALIEN AND INVASIVE SPECIES				
Ctenopharyngodon idella	Grass Carp	CIDE		
Cyprinus carpio	Common Carp	CCAR		
Gambusia affinus	Mosquito fish	GAFF		
Micropterus salmoides	Largemouth bass	MSAL		

10.4.2 Macroinvertebrates

Macroinvertebrate taxa expected under reference conditions include:
Perlidae, Hydropsychidae (>2 spp.), Heptageniidae, Baetidae (>2 spp.), Tricorythidae, Elmidae/Dryopidae, Atyidae, Leptophlebiidae, Hydracarina, Simuliidae, Coenagrionidae, Lestidae, Chlorocyphidae, Libellulidae, Nepidae, Naucoridae, Leptoceridae, Philopotamidae, Gyrinidae, Hydrophilidae, Planorbinae, and Sphaeridae.

10.5 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information provided with this report.

10.5.1 Index of Habitat Integrity (IIHI: C EC, 57.7%; RIHI: B EC, 70.7%)

The IIHI was rated a C/D (57.7%). This is mostly due to changes in hydrology due to inundation and flow modification. The RIHI is a C (70.7%) with the main impacts being substrate exposure due to diamond mining and the presence of exotic vegetation.

10.5.2 Diatoms (D EC)

Diatom results are based on a sample taken during 2007 and a 12 month data set taken during 2002-2003. The 2002-2003 data indicated continual pollution and during the survey the diatoms remained in a D EC for 7 of the 12 months. During the 12 month period there was some recovery to a C EC for 4 months but during the summer the biological water quality deteriorated to an E EC. The current sample indicated moderately polluted conditions with elevated nutrients and low organic pollution and the overall EC was set at a D.

10.5.3 Fish (C EC, 65.0%)

Eight of the ten expected fish species are still present within this RU although the FROC of some species have been reduced from reference conditions. The FROC of *L. kimberleyensis* has been altered potentially as a result of habitat deterioration (scouring). The FROC of *B. trimaculatus*, *B. paludinosus, T sparrmanii* and *Pseudocrenilabrus philander* have also been reduced and relates to loss of marginal vegetation cover and undercut banks. The presence of an aggressive alien predator *Micropterus salmoides* and habitat modifying species such as C*tenopharyngodon idella* and *Cyprinus carpio* may exacerbate the loss of suitable habitat for the above mentioned smaller species.

10.5.4 Macroinvertebrates (D EC, 57.1%)

Macroinvertebrates were sampled using the standard SASS5 method. Biotopes sampled include Stones in Current (SIC), Stones Out Of Current (SOOC) and limited Marginal Vegetation Out of Current (MVOOC). Gravel, Sand and some Mud (GSM) was sampled. For list of families present in the sample please refer to the MIRAI.

SASS results:
Oct 2010: SASS5 score: 56 No of Taxa: 12 ASPT: 4.7

Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Perlidae, Heptageniidae and Prosopistomatidae. Simuliidae, Corixidae and Hirudinea were more abundant than expected, while Potamonautidae and Caenidae were less abundant than expected.

10.5.5 Riparian vegetation (D EC, 50.7%)

The assessment was done using VEGRAI level 3. This site occurs within the Highveld Alluvial vegetation type, which has a least threatened conservation status with nearly 10% protected. The Bloemhof Dam Nature Reserve upstream of this site contributes towards the conservation status of this vegetation type.

Marginal Zone:
Reed and grass (include sedges) dominate this zone. Some *Phragmites australis* clumps occur with bare areas in between. Individual *Salix babylonica* trees occur. Impacts consist mainly of vegetation removal and footpaths. These impacts are mainly the result of recreational activities (fishermen) and livestock (footpaths). Exotic pioneers dominating are *Verbena bonariensis, V. tenuisecta, Bromus catharticus, Cirsium vulgare, Argemone ochroleuca,* etc. Reasonable to little vegetation cover and abundance occur. Species composition is not severely affected by exotics, however some pioneers occur. Some bank under cutting occurs in the marginal zone.

Non-marginal zone:
Mostly tree dominated state with shrubs occurring. Impacts consist mainly of vegetation removal, exotic vegetation (trees) and footpaths. These impacts are mainly due to recreation in the form of fishermen moving up and down the banks as well as grazing and trampling due to livestock. Exotic trees occur (*Eucalyptus* sp. and *Salix babylonica*) that also contribute towards less undergrowth with bare ground in some places. Species composition consists mainly of exotics with some indigenous riparian species. Indigenous species found are *Acacia karroo, Ziziphus mucronata, Rhus lancea, Gymnosporia buxifolia, Rhus pyroides, Diospyros lycioides*, etc. Some patchy grass cover consisting of *Cynodon dactylon, Bromus catharticus, Pennisetum villosum, Eragrostis plana*, etc. also occurs.

10.5.6 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 10.4.

Table 10.4 EWR 16: Causes and sources

	PES	Causes	Sources	F/NF
Rip veg	D	Vegetation removal.	Trampling/grazing and fishermen activity pressure.	NF
		Exotic invasion.	*Salix babylonica* and *Eucalyptus* sp., and non-woody weeds mainly.	
		Water quantity.	Reduced sedge cover in marginal zone due to increased dry season base flows, but the same cause has increased sedge cover and vigour in the lower zone.	F
		Bank undercutting and scouring.	Dam and weir upstream of site. Less natural freshets and minor floods occur to ensure bank inundation. Bank instability and the impact of silt hungry water contribute towards bank erosion.	

	PES	Causes	Sources	F/NF
Fish	C	Loss of habitat diversity as a result of flow modification.	Inundation Bloemhof Dam and flow modification.	F
		Decreased overhanging vegetation as cover for fish.	Habitat modifying fish species (C. *idella*) feeding aquatic and marginal vegetation. Increased bank erosion related to scouring and diamond mining activities.	NF
		Decreased water quality affect species with requirement for high water quality.	Increased sediments from diamond mines and agricultural areas.	
		Decreased species diversity and abundance (especially small species) as result of presence of aggressive alien predator (*M. salmoides*).	Presence of aggressive alien predatory species (*M. salmoides*) naturally spreading and introduced for recreation / angling.	
		Increased turbidity and disturbed bottom substrates.	Erosion and presence of bottom feeding alien (*C. carpio*).	
		Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Bloemhof Dam and other major downstream dams as well as weirs.	
Inverts	D	Loss of habitat diversity as a result of flow modification.	Inundation and flow modification due to Bloemhof Dam and the gauging weir.	F
		Decreased water quality affects taxa with high and moderate water quality requirements.	Agriculture and mining.	NF

10.6 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 10.5.

Table 10.5 EWR 16: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Rip veg	C	Stable			The vegetation has already responded to flow changes (due to dam and weir upstream) and it is improbable that the fishermen activity will decrease and that alien vegetation cover will increase so as to affect the current EC.	3
Fish	C	Stable			The upstream impoundments serve as a trap for sediments, nutrients and toxics, buffering the impact of upstream water quality modification. No other influences could be identified that would cause a direction change in the Present Ecological State of the fish assemblage.	3
Inverts	D	Stable			The macroinvertebrates have already reacted to the current conditions.	2

10.7 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 10.6. The Instream EC is a C (61.8%).

Table 10.6 EWR 16: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	2.5	90		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	2	80		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2	80		
FISH ECOLOGICAL CATEGORY	9.5	350	**65.0**	**C**
MACROINVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	2	90		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	3	100		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	90		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**7**	280	**57.1**	**D**
INSTREAM ECOLOGICAL CATEGORY (Excl confidence)		630	**60.5**	**C/D**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	3	0.60	39.00	
Confidence rating for **macroinvertebrate** information	2	0.40	22.84	
	5	1.00	61.84	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**C/D**	

To determine the EcoStatus, the VEGRAI EC and confidence is included in the EcoStatus assessment index (Table 9.7). The EcoStatus EC is a D.

Table 10.7 EWR 16: Instream EC

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**50.7**	**D**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	2.6	0.42	25.93
Confidence rating for riparian vegetation zone information	3.6	0.58	29.44
	6.2	1.00	55.37
ECOSTATUS	**EC**		**D**

10.8 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised in Table 10.8.

Table 10.8 EWR 16: EcoClassification results

2010		
Driver Components	**PES**	**Trend**
IHI: INSTREAM	C	
IHI: RIPARIAN	B	
DIATOMS (WQ)	D	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	D	Stable
INSTREAM	C/D	
RIPARIAN VEGETATION	D	Stable
ECOSTATUS	D	

10.9 SUITABILITY AS FUTURE MONITORING SITE

10.9.1 Biotopes present

Although the site is suitable for fish and macroinvertebrate sampling, the riparian vegetation is highly altered. The site occurs just downstream of Bloemhof Dam and the altered flow regime may be problematic for sampling.

Component	Advantages	Disadvantages	Conf
Rip veg	Easily accessible Zones with reasonable vegetation cover	Scouring took place due to the impacts of a dam and weir upstream of sites Bank instability occurs (bank slumping) Little vegetation cover in places Limited indigenous vegetation to work with Soil surface hard and impenetrable Many localised impacts Golf course and agricultural activities adjacent Adjacent town	3
Fish	Easily accessible wadeable areas Boulders provided some cover for smaller species. Substratum clear of sediments and algae Fast Deep provided some suitable habitat for larger species	Low diversity of flow velocities. Dominated by Fast Deep Substratum dominated by boulders Limited undercut banks and or overhanging vegetation.	4
Inverts	Good quantity of cobble biotope present Diversity of velocities present Diversity of instream habitats present	Limited GSM biotope present Limited diversity of marginal vegetation present, mainly sedges Site situated immediately downstream of a gauging weir	3

10.9.2 Site suitability

The site suitability of each site was assessed and is provided in Table 10.9. All scores are out of 5 with 5 referring to very high suitability (see below).

Very High: 4.1 – 5 High: 3.1 – 4
Moderate: 2.1 – 3 Low: 1.1 – 2
Very Low: 0 – 1

Table 10.9 EWR 16: Biophysical site suitability

Site	Rip veg	Fish	Inverts	Average	Median	Max	Min	Comments
EWR 16	2	2	2	2	2	2	2	**Low** suitability for biotic component monitoring. Low diversity of flow velocities and too many impacts in the form of recreational activities (golf course, fishing, etc.), exotic vegetation, dam and weir upstream, occurs.

11 EWR 18: SCHMIDTSDRIFT (VAAL RIVER) – OSAEH 29.4

OSAEH 29.4 was assessed as part of the Lower Vaal Reserve study, and the results are provided in the summary report (Technical report 1). The results provided below are based on the assessment undertaken during October 2010 as part of this study.

11.1 SITE DESCRIPTION

Location	EWR 18 Schmidtsdrift/OSAEH 29.4	**Altitude**	1239 m
Longitude	24.07578	**Latitude**	-28.70758
EcoRegion	Southern/Central Kalahari/Ghaap plateau 29.02; 30.01	**Quaternary catchment**	C92B
Water Management Area	Lower Vaal	**Geomorphological zone**	Lower Foothills

The site consists of a deep, wide (approximately 60 m), open water channel. Reeds, riparian vegetation and water grass (*Potamogeton* and *Ceratophyllum)* are dense, and the substrate is very muddy with heavy siltation. The sampling site has a steep gradient and becomes deep very quickly. Together with the mud and silt substrate, it makes this site non-wadeable. Low habitat diversity was available for fish sampling as well as for macroinvertebrate sampling. The Slow Deep (SD) habitat is available for fish, with abundant marginal vegetation (reeds) present and riparian trees and grass. Some Slow Shallow (SS) biotope is also available. Macroinvertebrate habitat available includes marginal vegetation, sand and mud. The surrounding land use consists of natural fields and pastures due to agriculture in the area. Diamond mining also occurs in the area.

Figure 11.1 OSAEH 29.4: Uniform, deep, wide channel (SD dominant)

11.2 BIOTIC SAMPLING

At the time of sampling, fish habitat type consisted of Slow Deep (SD) and Slow Shallow (SS) on the river margin with abundant aquatic vegetation for cover. The substratum consisted of mud and silt. Serious sedimentation occurred at the site. No benthic growth was observed and no odours could be detected. The water was murky and turbid. Serious to large impacts on the site are upstream weirs and abstraction for irrigation which causes flow modification at the site. Bed modification is serious due to sedimentation from diamond mining and agriculture, as well as run-off from Schmidtsdrift. Some exotic vegetation removal and encroachment is visible. Erosion is limited at the site but is considered moderate throughout the catchment.

11.2.1 Fish

The fish sampling was conducted at the site during October 2010. A river stretch of approximately a 100 m long, was sampled representing SD and SS habitat. Two depth classes were sampled for 45 minutes in this stretch of river. Sampling and data analysis was followed according to Kleynhans (2007). A summary of the site conditions during sampling is provided below. Abundance of habitat was rated as:

- 0 = absent 1 = rare
- 2 = sparse 3 = moderate
- 4 = abundant 5 = very abundant

Fish velocity-depth classes and cover present at the site

SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
5	5	0	0
Overhanging vegetation			
3	3	0	0
Undercut banks and root wads			
0	0	0	0
Substrate			
0	0	0	0
Aquatic macrophytes			
4	4	0	0
Water Column			
5	5	0	0

Habitats sampled and effort

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Electro shocker (min)	15 min	30 min	0 min	min

11.3 DATA AVAILABILITY

Detailed information regarding available data is provided in Table 11.1.

Table 11.1 OSAEH 29.4: Summary of data availability

Comp	Data availability	Conf
IHI	Google Earth imagery. Information from Lower Vaal Reserve study.	3
Riparian vegetation	Google Earth imagery. Current Google Earth imagery of the site and site context. Data collected from field assessment during October 2010. Ecological reports and specialist assessments for this study; previous Reserve determination report SANBI floristic distribution data (2009) Literature: **Kleynhans C.J, MacKenzie J., Louw M.D.** 2007a. Module F: Riparian Vegetation Response Assessment Index in River Classification: Manual for EcoStatus Determination (version 2). Joint Water Commission and Department of Water Affairs and Forestry report. WRC Report No. TT333/08. **Low B.A., Rebello A.G.** (eds) 1998. Vegetation of South Africa, Lesotho and Swaziland**.** Department of Environmental Affairs and Tourism, Pretoria. **Mucina L. & Rutherford M.C.** (eds) 2006. Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19*. South African National Biodiversity Institute, Pretoria. **Van Wyk B. & Van Wyk P**. 2009. Field Guide to trees of Southern Africa. 12th Impression. Struik Nature Publishers, Cape Town.	4

Comp	Data availability	Conf
Fish	Google Earth imagery. One site visit and fish sampling during October 2010. South African Institute of Aquatic Biodiversity (SAIAB) data base (2006). **Kleynhans, C.J., Louw, M.D & Moolman, J**. 2007b. Module D (Volume 2): Reference Frequency of Occurrence of Fish Species in South Africa: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry Report. WRC Report No. TT330/08. Water Research Commission, Pretoria, South Africa. **Rivers Data base** (2007): *Database on fish distribution in South African Rivers*. **Scott *et al.*** (2006): *Atlas of Southern African Freshwater Fishes*.	4
Inverts	Google Earth imagery. One site visit and fish sampling during October 2010. SASS5 surveys undertaken to determine the PES (Rivers Database). Previous Reserve determination report.	2

11.4 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 11.2. Additional information on fish, macroinvertebrate and riparian vegetation reference conditions are also provided.

Table 11.2 OSAEH 29.4: Reference conditions

Comp	Reference conditions	Conf
Riparian vegetation	Savanna Biome; Eastern Kalahari Bushveld Bioregion and the Schmidtsdrif Thornveld Vegetation Type (Mucina & Rutherford, 2006). **Marginal Zone: E**xpect narrow zone dominated by non-woody vegetation, a mixture of reed, sedge and hydrophilic grasses and dicots. **Lower Zone:** As marginal, but with a woody component consisting of *Salix mucronata* where alluvial lateral bars exist. **Upper Zone:** Alluvial lateral bars dominated by woody obligate and preferential species, with grass cover where woody species do not occur **MCB:** As upper, but with higher density of woody vegetation. **Floodplain:** Grassland floodplain with woody clumps in places.	3.5
Fish	Reference conditions as set for the NRHP site, C9VAALSCHMI, (Kleynhans *et al.,* 2007b), which is also the OSEAH 29.4 sampling site, was used as a starting point for setting reference conditions. See Table 10.3 for a list of the reference fish species.	4
Inverts	Reference conditions are based on professional judgement and Rivers Database information. The reference SASS5 score is 200 and the ASPT is 6.5.	2

11.4.1 Fish

Reference conditions broadly refer to “expectations on the state of aquatic biological communities in the absence of human disturbance and pollution”. In the context of this report, it refers specifically to the fish species present in a particular river reach and their frequency of occurrence under reference habitat conditions. Reference conditions as set for the NRHP site, C9VAALSCHMI, (Kleynhans *et al.,* 2007b), which is also the OSEAH 29.4 sampling site, was used as starting point for setting reference conditions.

Professional opinion and experience; sampling; and habitat and site observations were further used to obtain a derived FROC from the reference FROC, based on the species habitat and condition preferences and tolerances (Table 11.3). An exotic fish species *Cyprinus carpio* is also listed for this system.

Eleven indigenous fish species are expected under reference conditions and are listed in Table 11.3.

Table 11.3 OSAEH 29.4: Reference fish species

Expected Reference and Habitat derived FROC of fish at OSAEH 29.4 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Austroglanis sclateri	Rock catfish	ASCL	3	1
Barbus anoplus	Chubbyhead barb	BAEN	3	2
Barbus paludinosus	Straightfin barb	BANO	3	2
Barbus trimaculatus	Threespot barb	BKIM	3	1
Labeobarbus aeneus	Smallmouth yellowfish	BNEE	3	2
Labeobarbus kimberleyensis	Largemouth yellowfish	BPAU	3	1
Clarias gariepinus	Sharptooth catfish	BTRI	3	3
Labeo capensis	Orange River labeo	CGAR	3	2
Labeo umbratus	Moggel	LCAP	3	2
Pseudocrenilabrus philander	Southern mouthbrooder	LUMB	3	2
Tilapia sparrmanii	Banded tilapia	PPHI	3	2
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%) 3 = present at about >25 - 50 % of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)				
ALIEN AND INVASIVE SPECIES				
Cyprinus carpio	Common Carp	CCAR		

The landowner stated that *C. gariepinus*, *C. carpio*, *L. aeneus* and *L. capensis* are regularly caught with angling.

11.4.2 Macroinvertebrates

Macroinvertebrate taxa expected under reference conditions include:
Hydropsychidae (>2 spp.), Heptageniidae, Baetidae (>2 spp.), Tricorythidae, Elmidae/Dryopidae, Atyidae, Leptophlebiidae, Hydracarina, Simuliidae, Coenagrionidae, Naucoridae, Hydroptilidae, Tipulidae, Corbiculidae, Caenidae, Gerridae, Veliidae/ Mesoveliidae, Dytiscidae/Noteridae, Gyrinidae, Ceratopogonidae, Porifera, Hydrophilidae, Turbellaria, Potamonautidae, Corixidae, Chironomidae, Sphaeriidae, Oligochaeta, Tabanidae, Gomphidae, Pleidae, Libellulidae, Ancylidae, Leptoceridae, Hydrometridae, Chlorolestidae, Lestidae, Chlorocyphidae, Philopotamidae, Aeshnidae, Notonectidae, Culicidae, Muscidae, Belostomatidae, Nepidae, Lymnaeidae, Planorbidae and Thiaridae.

11.5 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information provided with this report.

11.5.1 Index of Habitat Integrity (IIHI: C, 76.2%; RIHI: B/C, 72.5%)

The IIHI is a C (76.2%). This is mostly due to poor bed conditions, in that elevated levels of fine sediment have reduced water clarity. The poor condition of the non-marginal zone has also influenced the instream integrity. The RIHI is a B/C (72.5%) with the main impacts being poor bank conditions due to alien invasive species, especially *Eucalyptus camuldensis* and substrate exposure due to clearing. Reduced base flows and small floods also facilitate an increase in marginal and lower zone vegetation and flow regulation promotes reed expansion and density.

11.5.2 Diatoms (C/D EC)

The assessment is based on single samples taken during the current assessment and Reserve assessment. The overall EC of this site is a C/D. Pollution levels have increased drastically at this

site especially organic pollution. The site is very heavily polluted with moderate oxygen saturation and continuously elevated levels of organically bound nitrogen.

11.5.3 Fish (D EC, 54.1%)

All of the eleven species expected under reference conditions are still expected to be present under the present conditions at this site and in the river. Serious siltation reduced the habitat suitability (substrate – cobbles and rocks) for *A. sclateri*, *L. kimberleyensis*, *L. capensis*, *L. aeneus*, and *L. umbratus*, reducing the FROC (habitat and spawning substrate loss). Lower flows result in loss of other habitat such as riparian vegetation overhang and undercut banks, resulting in a lower FROC for *B. trimaculatus*, *B. paludinosus*, *B. anoplus*, *A. sclateri*, *P. philander*, and *T. sparrmanii*. Flow modification resulting in lower flows resulted in a loss of FD and FS habitats, causing a loss of water column in these habitats and a lower FROC for *A. Sclateri*, *L. aeneus*, *L. kimberleyensis*, *L. capensis*, and *L. umbratus*. It is expected that species which are moderately intolerant to no flow conditions (*L. aeneus*, *L. kimberleyensis*, *A. sclateri* and *L. capensis*) will still be present as they will survive and be sustained in the current habitat for extended periods, but that their spawning success and recruitment will be reduced, resulting in a lower FROC for each. Loss of feeding habitat i.e. rocks and cobbles due to siltation also reduce the FROC of these species (including *L. umbratus*). The FROC of some species is expected to have been reduced due to deterioration of certain habitat conditions.

Due to flow modification and reduced flows and floods there is a loss of FD and FS habitats as well as substrate as cover (due to siltation), reducing the FROC of *A. sclateri*, *L. aeneus*, *L. umbratus*, *L. capensis* and *L. kimberleyensis*. Due to reduced flows there is also a loss in riparian vegetation overhang, bank undercut, and root wads as cover resulting in a loss of preferred habitat and a reduced FROC for *B. anoplus*, *B. paludinosus*, *B. trimaculatus*, *P. philander*, and *T. sparrmanii*. Large pools are present and all the species will be able to utilise the pools as cover and refugia. Good marginally vegetated spawning habitat is present for spawning during high floods, and pools are present as refugia and nursery area, after floods. The presence of carp, which can prey on fish eggs and causes bio-turbation, may also negatively impact on the fish species present in the system. The FROC of *C. gariepinus* (quiet water benthic species) is unchanged from reference as this species are tolerant to no-flow conditions. Habitat availability is also adequate in terms of its habitat preferences (SD, SS, and Cover – water column, instream veg., and marginal aquatic veg. etc.).

11.5.4 Macroinvertebrates (C/D EC, 61%)

Macroinvertebrates were sampled using the standard SASS5 method. Habitat available was Marginal vegetation out of current (MVOC), Aquatic vegetation (AV), Gravel sand and mud (GSM). No stones were sampled at the site. For list of families present in the sample please refer to the MIRAI.

SASS results:

Oct 2010: SASS5 score: 81 No of Taxa: 17 ASPT: 4.8

Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Baetidae (>2 spp), Heptageniidae, Hydropsychidae (>2 spp), Atyidae, Chlorocyphidae, Chlorolestidae, Elmidae, Gerridae, Hydracarina, Hydrometridae, Leptophlebiidae, Lestidae, Philopotamidae, Tricorythidae, and Vellidae/ Mesovellidae.

11.5.5 Riparian vegetation (C EC, 72.5%)

The assessment was done using VEGRAI level 4. The overall score for the site is carried by the marginal and lower zones which are in much better condition than the upper zone or MCB.

Marginal Zone:
Only the left bank was assessed and comprised of three components:
1) High density reed beds,
2) Steep narrow alluvial banks with grass and sedge mix,
3) Shaded and rooted *S. mucronata* stands where alluvial bars exist.

Lower Zone:
Same as marginal zone, with *S. mucronata* density slightly higher.

Upper Zone:
Alluvial lateral bars with low woody density, dominated by non-woody species, mostly annual alien weeds that have responded to recent disturbance, including floods.

Macro Channel Bank (MCB):
Dominated by woody species which form thicket along the river, dominant species include *Combretum erythrophyllum, Acacia karoo* and *Ziziphus mucronata*.

Floodplain:
Present, but not assessed due to high manipulation i.e. farming, diamond mining and current grading by dozers.

11.5.6 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 11.4.

Table 11.4 OSAEH 29.4: Causes and sources

	PES	Causes	Sources	F[1]/NF[2]
Rip veg	C	Reduced cover of indigenous riparian obligate species, mainly on upper zone and floodplain.	Physical clearing, removal, mining and replacement by alien vegetation.	NF
		Altered species composition.	Up to 60% cover by annual alien species, mainly weeds.	
		Increased sedge and reed cover.	Flow regulation and reduced flooding disturbance facilitates an increase in reed and sedge cover and density in the marginal and lower zone.	F
Fish	D	Loss of mainly FD and FS habitat as a result of flow modification (especially during naturally low flow periods).	Weirs and water abstraction for farming and irrigation upstream.	F
		Lower breeding success and recruitment for fish = lower FROC.	Lower, less and/or no natural flushes and smaller floods. Flow modification due to weirs and water abstraction for farming and irrigation upstream.	
		Loss of species diversity or numbers due to loss of habitat diversity due to lower flows.	Flow modification due to weirs and water abstraction for farming and irrigation upstream.	
		Loss of habitat with substrate (cobbles and rock), and water column in FD and FS due to lower than natural flows.	Flow modification due to weirs and water abstraction for farming and irrigation upstream.	
		Loss of vegetation overhang, root wads, and habitat for cover.	Reduced flows – flow modification.	
		Loss of habitat – substrate – due to siltation.	Lower flows, floods and flushes for flushing sediment from substrate.	
		Decreased species diversity and abundance due to presence of carp.	Presence of alien species (carp) introduced for aquaculture and angling.	NF

	PES	Causes	Sources	F[1]/NF[2]
		Serious siltation and loss of substrate and habitat.	Mining, agriculture, and erosion upstream.	
		Presence of weirs as migration barriers (breeding, feeding and dispersal), also causing loss of habitat of some species (inundation).	Weirs in area.	
Inverts	C/D	Bed modification.	Urbanization, agriculture and diamond mining.	NF
		Deteriorating water quality.	Agriculture.	

11.6 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 11.5.

Table 11.5 OSAEH 29.4: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Rip veg	C	Stable			Alien species mainly annual weeds	3
Fish	D	Stable			The site may deteriorate further if mining continues at an increased rate and adequate floods are not released for flushing of sediments. The site was surveyed during the dry season base flow period (low flow), and certain fish species with a moderate intolerance to no flows were sampled It is expected that fish will use the pools and SD habitat for refuge areas, and all of the expected species are still expected to be present but at lower FROCs. Marginal spawning habitat is present for some species, and can be utilized by fish during higher flows or floods.	3
Inverts	C/D	Stable			The macroinvertebrates have already reacted to the current conditions.	1

11.7 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 11.6. The Instream EC is a D (56.4%).

Table 11.6 OSAEH 29.4: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	4	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	4	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	4	100		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	90		
FISH ECOLOGICAL CATEGORY	15	390	**54.1**	**D**
MACROINVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	2	100		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	2	100		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	100		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**6**	300	**61**	**C/D**
INSTREAM ECOLOGICAL CATEGORY (Excl confidence)		690	**57.0**	**D**

INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	Confidence rating	Proportions	Modified weights
Confidence rating for **fish** information	3	0.67	36.07
Confidence rating for **macroinvertebrate** information	1.5	0.33	20.33
	4.5	1.00	56.40
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**D**

To determine the EcoStatus, the VEGRAI EC and confidence is included in the EcoStatus assessment index (Table 11.7). The EcoStatus EC is a C.

Table 11.7 OSAEH 29.4: Instream EC

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**72.5**	**C**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	2.5	0.40	22.38
Confidence rating for riparian vegetation zone information	3.8	0.60	43.73
	6.3	1.00	66.11
ECOSTATUS	**EC**		**C**

The EcoStatus is an E, mainly due to the poor condition of the riparian vegetation, which is impacted by exotic species. During future monitoring, the focus should be on the instream condition during (D EC).

11.8 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised in Table 11.8.

Table 11.8 OSAEH 29.4: EcoClassification results

Driver Components	PES	Trend
IHI: INSTREAM	C	
IHI: RIPARIAN	C	
DIATOMS (WQ)	C/D	
Response Components	**PES**	**Trend**
FISH	D	Stable
MACRO INVERTEBRATES	C/D	Stable
INSTREAM	D	
RIPARIAN VEGETATION	C	Stable
ECOSTATUS	C	

11.9 SUITABILITY AS FUTURE MONITORING SITE

11.9.1 Biotopes present

Good quantity and quality of marginal vegetation is present for macroinvertebrate sampling. No SOOC and SIC biotopes were present for sampling. Marginal, aquatic vegetation and the water column provide abundant fish cover while Slow Deep (SD) and pool habitat provide abundant water column cover for fish refugia. The site will provide good spawning area during flooding with ample marginal vegetation available for the spawning needs of certain fish species.

Sampling at this site is difficult as the river is non-wadeable due to the steep gradient of the river. Limited biotopes occur for biotic sampling, and the riparian zone is very dense. Fish habitat diversity is low and siltation is problematic. Habitat requirements (flow-depth categories and cover) of most expected species not well represented at site and there is habitat loss due to flow modification, although limnophilic habitat requirements are still met. A limiting factor is serious siltation which limits sampling success, and reduces habitat suitability for some species. Easy access to site but the site is basically non-wadeable.

Component	Advantages	Disadvantages	Conf
Rip veg	Riparian alluvial habitats available Riparian obligate species present (rheophytes, helophytes and bank species) and mostly dominant at the site	High degree of alien species presence High degree of bank and floodplain manipulation: diamond mining and agriculture Cannot cross the river without a boat	5
Fish	Marginal and instream aquatic veg., water column, abundant for fish cover. SD and pool type habitat abundant for water column cover and refugia. No NPS pollution observed. Good spawning area during high floods with ample	Up-stream water abstraction and in river reach. Reduced base flows. Flow modification due to weirs and abstraction upstream – decrease in base flows and floods, and impact on seasonality	4

	marginal veg. for spawning needs of certain fish. Perennial flow in this reach. Abundant nursery habitat for juvenile fish in form of abundant aquatic vegetation.	of smaller floods. Catchment scale impacts – erosion in catchment, weirs and water abstraction. Heavy siltation. Diamond mining in area - siltation. Low habitat diversity. FS and FD absent. Substrate absent (rocks and cobbles etc.) Non-wadeable.	
Inverts	Good quantity and diversity of marginal vegetation	No SOOC and SIC biotope present GSM biotope mainly mud and sand, no gravel.	1.5

11.9.2 Site suitability

The site suitability of each site was assessed and is provided in Table 11.9. All scores are out of 5 with 5 referring to very high suitability (see below).

Very High: 4.1 – 5 High: 3.1 – 4
Moderate: 2.1 – 3 Low: 1.1 – 2
Very Low: 0 – 1

Table 11.9 OSAEH 29.4: Biophysical site suitability

Site	Rip veg	Fish	Inverts	Average	Median	Max	Min	Comments
OSAEH 29.4	3	1.5	1	1.83	1.5	3	1	**Low** suitability for biotic component monitoring. High degree of impacts at site. Limited habitat availability, non wadeable. Exotic riparian vegetation species and bank modification.

12 OSAEH 11.21: KORANNASPRUIT

12.1 SITE DESCRIPTION

Location	OSAEH 11.21	**Altitude**	1350 m
Longitude	-29.08107	**Latitude**	26.62615
EcoRegion	Highveld 11.03	**Quaternary catchment**	C52C
Water Management Area	Upper Orange	**Geomorphological zone**	Foothill

This site is situated downstream of a large dam, upstream of the confluence of the Modder River. The width of the stream varies from 2 – 15 cm. The substrate is dominantly sand and mud, with silt covering the substratum in the pool section. Abundant marginal vegetation occurs, including reeds, sedges and overhanging trees. Aquatic vegetation is also present. The surrounding land use is natural fields for grazing. The river is unchannelled and is partly shaded by the riparian trees. Bank undercutting and root wads occur at the site. GSM is biotope available for sampling.

Figure 12.1 OSAEH 11.21: Pool with riparian vegetation overhang and marginal sedge

12.2 BIOTIC SAMPLING

At the time of sampling, no flow was present and the site consisted of pool sections only. No stones, cobbles or bedrock substrate were observed. The site was heavily eroded, with thick sedimentation occurring in the pools. The water colour was brown and very turbid. No odours were detected. No exotic macrophytes, solid waste disposal and vegetation removal were observed. No exotic vegetation encroachment was present. The water level in the pools did not reach the roots or stems of the marginal vegetation.

12.2.1 Fish

The fish sampling was conducted at the site during October 2010. At the time of sampling there was no flow (low flow dry season). Isolated pools in the river bed were sampled, for 45 minutes. The pools sampled were relatively shallow with average depth sampled at 0.3 m. No Fish were sampled. Sampling and data analysis was followed according to Kleynhans (2007). A summary of the site conditions during sampling is provided below. Abundance of habitat was rated as:

- 0 = absent
- 1 = rare
- 2 = sparse
- 3 = moderate
- 4 = abundant
- 5 = very abundant

Fish velocity-depth classes and cover present at the site

	Pools
	4
Overhanging vegetation	
	4
Undercut banks and root wads	
	3
Substrate	
	0
Aquatic macrophytes	
	0
Water Column	
	4

12.3 DATA AVAILABILITY

Detailed information regarding available data is provided in Table 12.1.

Table 12.1 OSAEH 11.21: Summary of data availability

Comp	Data availability	Conf
IHI	Google Earth imagery. Information from Lower Vaal Reserve study.	3
Riparian vegetation	Current Google Earth imagery of the site and site context. Data collected from field assessment during October 2010. Ecological reports and specialist assessments for this study; previous Reserve determination report SANBI floristic distribution data (2009) Literature: **Kleynhans C.J, MacKenzie J., Louw M.D.** 2007a. Module F: Riparian Vegetation Response Assessment Index in River Classification: Manual for EcoStatus Determination (version 2). Joint Water Commission and Department of Water Affairs and Forestry report. WRC Report No. TT333/08. **Low B.A., Rebello A.G.** (eds) 1998. Vegetation of South Africa, Lesotho and Swaziland**.** Department of Environmental Affairs and Tourism, Pretoria. **Mucina L. & Rutherford M.C.** (eds) 2006. Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19*. South African National Biodiversity Institute, Pretoria. **Van Wyk B. & Van Wyk P**. 2009. Field Guide to trees of Southern Africa. 12th Impression. Struik Nature Publishers, Cape Town.	4
Fish	Google Earth imagery. One site visit and fish sampling during October 2010. **Kleynhans, C.J., Louw, M.D & Moolman, J**. 2007b. Module D (Volume 2): Reference Frequency of Occurrence of Fish Species in South Africa: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry Report. WRC Report No. TT330/08. Water Research Commission, Pretoria, South Africa. **Rivers Data base** (2007): *Database on fish distribution in South African Rivers*. **Scott *et al.*** (2006): *Atlas of Southern African Freshwater Fishes*.	2.5
Inverts	Google Earth imagery. One site visit and fish sampling during October 2010. SASS5 surveys undertaken to determine the PES (Rivers Database). Previous Reserve determination report.	2

12.4 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 12.2. Additional information on fish, macroinvertebrate and riparian vegetation reference conditions are also provided.

Table 12.2 OSAEH 11.21: Reference conditions

Comp	Reference conditions	Conf
Riparian vegetation	Grassland Biome, with Winburg Grassy Shrubland vegetation type (Mucina & Rutherford, 2006). **Marginal Zone:** Dominated by non-woody vegetation, a mix of sedges and hydrophylic dicots and grasses. A small fairly low woody component expected, mainly *Salix mucronata.* **Lower Zone:** Dominated by grasses in keeping with the Vegetation Type. **Upper Zone:** Dominated by grasses (mainly terrestrial grasses), with woody components where substrate becomes rocky and steep (*Diospyros lycioides* mainly).	3
Fish	Reference conditions as set for the NRHP site, C5KORAMOCKE, (Kleynhans *et al.,* 2007b), which is also the OSEAH 11.21 sampling site, was used as a starting point for setting reference conditions. See Table 11.3 for a list of the reference fish species.	3
Inverts	Reference conditions are based on professional judgement and Rivers Database information. The reference SASS5 score is 220 and the ASPT is 7.	2

12.4.1 Fish

Reference conditions broadly refer to "expectations on the state of aquatic biological communities in the absence of human disturbance and pollution". In the context of this report, it refers specifically to the fish species present in a particular river reach and their frequency of occurrence under reference habitat conditions. Reference conditions as set for the NRHP site, C5KORAMOCKE, (Kleynhans *et al.,* 2007b), which is also the OSEAH 11.21 sampling site, was used as starting point for setting reference conditions.

Professional opinion and experience; sampling; and habitat and site observations were further used to obtain a derived FROC from the reference FROC, based on the species habitat and condition preferences and tolerances (Table 12.3).

Six indigenous fish species are expected under reference conditions and are listed in Table 12.3.

Table 12.3 OSAEH 11.21: Reference fish species

Expected Reference and Habitat derived FROC of fish at OSAEH 11.21 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Labeobarbus aeneus	Smallmouth yellowfish	BAEN	3	1
Barbus anoplus	Chubbyhead barb	BANO	3	1
Labeobarbus kimberleyensis	Largemouth yellowfish	BKIM	3	0
Clarias gariepinus	Sharptooth catfish	CGAR	3	3
Labeo capensis	Orange River labeo	LCAP	3	1
Labeo umbratus	Moggel	LUMB	3	1
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%) 3 = present at about >25 - 50 % of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)				
ALIEN AND INVASIVE SPECIES				
Cyprinus carpio	Common Carp	CCAR		

12.4.2 Macroinvertebrates

Macroinvertebrate taxa expected under reference conditions include:
Hydropsychidae (>2 spp.), Heptageniidae, Baetidae (>2 spp.), Tricorythidae, Elmidae/Dryopidae, Atyidae, Leptophlebiidae, Hydracarina, Simuliidae, Coenagrionidae, Naucoridae, Hydroptilidae, Tipulidae, Corbiculidae, Caenidae, Gerridae, Veliidae/ Mesoveliidae, Dytiscidae/Noteridae,

Gyrinidae, Ceratopogonidae, Porifera, Hydrophilidae, Turbellaria, Potamonautidae, Corixidae, Chironomidae, Sphaeriidae, Oligochaeta, Tabanidae, Gomphidae, Pleidae, Libellulidae, Ancylidae, Leptoceridae, Hydrometridae, Chlorolestidae, Lestidae, Chlorocyphidae, Philopotamidae, Aeshnidae, Notonectidae, Culicidae, Muscidae, Belostomatidae, Nepidae, Lymnaeidae, Planorbidae and Thiaridae.

12.5 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information provided with this report.

12.5.1 Index of Habitat Integrity (IIHI: D, 42.8%; RIHI: D, 53.4%)

The IIHI is a D (42.8%) and this is mostly due to poor bed conditions, with elevated levels of fine alluvia, and altered flow regimes with reduced base flows and flooding and increased occurrence of zero flows. The RIHI is a D (53.4%) with the main impacts being poor bank conditions due to a high degree of erosion at and upstream of the site, with trampling pressure exacerbating the situation.

12.5.2 Diatoms (D EC)

The assessment is based on single sample taken during the current assessment. Due to the zero flow and the presence of cattle, organic pollution levels are very high and the EC was a D with critical pollution levels.

12.5.3 Fish (E EC, 35.4%)

Most of the fish species (5 out of 6) expected under reference conditions are still expected to be present under the present conditions at this site and in the river, although the FROC of some species have been drastically reduced from reference conditions, with the loss of one species (*L. kimberleyensis*). This is mainly due to no flow conditions experienced during the time of the survey (low flow – base flow dry season).

It is expected that the fish species will make use of the Korannaspruit as spawning area during high floods, and that they will use the pools in the Korannaspruit as refugia and nursery area, after floods. But the reduced base flows and loss of longitudinal connectivity, as well as heavy siltation due to the impacts as discussed in this document, are causes of concern for the fish utilising this system, and the suitability of the site for monitoring.

Three of the expected fish species are moderately intolerant and two are moderately tolerant to no flow conditions, explaining the lower derived FROC for this site. The main impacts on these fish are decreased flows, loss of water column in FD and FS as cover, siltation and loss of substrate as cover, and the absence of instream aquatic macrophytes. The presence of carp, which can prey on fish eggs and causes bio-turbation, will also negatively impact on the fish species present in the system.

Labeobarbus kimberleyensis is, however, not expected to occur anymore due to a major loss of its preferred habitat conditions (flow and substrate). The main impacts on this fish are decreased flows, loss of water column in FD and FS as cover, siltation and loss of substrate (cobbles and rock) as cover.

Main impacts on the fish: A large dam upstream, smaller weirs and water abstraction for irrigation are the main reasons for the flow modification i.e. reduced dry season base flow, as experienced during the survey, and the reduced FROC.

12.5.4 Macroinvertebrates (D/E EC, 41.4%)

Macroinvertebrates were sampled using the standard SASS5 method. Sampling was restricted to pools at the site as there was no flow. Habitat available was Marginal vegetation out of current (MVOC), Gravel sand and mud (GSM). For list of families present please refer to the MIRAI.

SASS results:

Oct 2010: SASS5 score: 55 No of Taxa: 15 ASPT: 3.7

Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Baetidae (>2spp), Hydropsychidae (>2spp), Aeshnidae, Atyidae, Elmidae, Hydracarina, Leptophlebiidae, Tricorythidae, and Vellidae/ Mesovellidae.

The low SASS5 scores observed during the time of sampling were due to a lack of key habitat for macroinvertebrates as there was no flow. The conditions would have been different had the river been flowing and for a while. The reason for no flow at the site could be due to impoundments or/and farm dams upstream.

12.5.5 Riparian vegetation (C EC, 76.9%)

The assessment was done using VEGRAI level 4.

Marginal Zone:

Dominated by alluvium, deep mud in pools, all cobbles embedded. Marginal zone vegetation a mix of sedges and grasses and *Salix mucronata* overhang.

Lower Zone:

As the marginal zone but with steeper banks and a high degree of erosion which has been exacerbated by high grazing and trampling pressure.

Upper Zone and MCB:

Mixed grass and woody thickets (see species lists – provided electronically).

12.5.6 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 12.4.

Table 12.4 OSAEH 11.21: Causes and sources

	PES	Causes	Sources	F/NF
Rip veg	C	Reduced cover of indigenous riparian obligate species, especially in the marginal and lower zones.	High trampling pressure around pools, with associated grazing.	NF
		Altered species composition.	Low cover and presence of alien species (only annuals noted), but trampling and grazing pressure also reduces grass cover which caters for an increase in sedge density and cover.	
		Reduced vigour and vegetation cover, especially in marginal and lower zone.	Zero flow at the time, base flows seem to be reduced with no spring flush or vigour at the site in October.	F
Fish	E	Loss of habitat (loss of all flow depth classes) diversity as a result of flow modification (especially during naturally low flow periods).	Large dam, smaller weirs and water abstraction for farming and irrigation and small villages upstream.	F
		Lower breeding success and recruitment for fish = lower FROC.	Lower, less and/or no natural flushes and floods. Flow modification due to dam etc.	
		Fluctuating daily oxygen and temperature levels.	No Flow. Flow modification due to dam etc.	
		Decreased substrate quality due to embedding.	Lower, less and/or no natural flushes and floods. Flow modification due to dam etc.	

	PES	Causes	Sources	F/NF
		Decreased aquatic vegetation as cover for fish.	Increased exotic riparian vegetation and shading. Less light penetration.	
		Excessive erosion and increased sedimentation resulting in deterioration of substrate as habitat (clogging and loss of important spawning habitats, and cover etc.).	Local and catchment scale bank erosion due to cattle farming – trampling, and bad farming practices.	
		Decreased species diversity and abundance due to presence of carp.	Presence of alien species (carp) introduced for aquaculture and angling.	NF
		Siltation, enrichment of water and anaerobic decomposition.	Cattle farming, trampling – erosion and excrement.	
		Possible pollution and enrichment of water.	Fertilizers.	
		Presence of dams and weirs as migration barriers (breeding, feeding and dispersal), also causing loss of habitat of some species (inundation).	Dam and other smaller weirs in area.	
Inverts	D/E	No flow. Limited habitat for macroinvertebrates.	Agriculture	F
		Water quality and associated benthic growth.		NF

12.6 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 12.5.

Table 12.5 OSAEH 11.21: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Rip veg	C	Stable			Vegetation at the site has reached stable reaction to current impacts	3
Fish	E	Stable			The site was surveyed during the dry season base flow period (low flow), and there was no flow present – three species are moderately intolerant to no flows. It is expected that fish will use the pools for refuge areas, but most of the species are expected to disappear when water levels in the pools become too low and environmental conditions too harsh. The fish can and will only be able to use this river for spawning purposes during high flows/floods. And fish trapped in the pools will die of if conditions become too harsh (temp, oxygen, turbidity, predation, cattle trampling and excrement etc.) The PES is an E, and with the current flow regulation and modification it will not improve, unless there is a regulated minimum baseflow throughout all the seasons. Fish will always repopulate from the Modder River into the Korannaspruit for spawning and feeding and nursery during high flows or floods.	2.5
Inverts	D/E	Stable			The macroinvertebrates have already reacted to the current conditions.	1

12.7 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 12.6. The Instream EC is a D/E (37.8%).

Table 12.6 OSAEH 11.21: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	5	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	4	90		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	4	90		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	70		
FISH ECOLOGICAL CATEGORY	16	350	**35.4**	**E**
MACROINVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	2	100		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	2	100		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	100		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**6**	300	**41.4**	**D/E**
INSTREAM ECOLOGICAL CATEGORY (Excl confidence)		650	**37.8**	**D/E**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	3	0.60	21.24	
Confidence rating for **macroinvertebrate** information	2	0.40	16.56	
	5	1.00	37.80	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**D/E**	

To determine the EcoStatus, the VEGRAI EC and confidence is included in the EcoStatus assessment index (Table 12.7). The EcoStatus EC is an E.

Table12.7 OSAEH 11.21: Instream EC

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**27.7**	**E**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	2.6	0.41	15.36
Confidence rating for riparian vegetation zone information	3.8	0.59	16.45
	6.4	1.00	31.80
ECOSTATUS	**EC**		**E**

12.8 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised in Table 12.8.

Table 12.8 OSAEH 11.21: EcoClassification results

Driver Components	PES	Trend
IHI: INSTREAM	D	
IHI: RIPARIAN	D	
DIATOMS (WQ)	D	
Response Components	**PES**	**Trend**
FISH	E	Stable
MACRO INVERTEBRATES	D/E	Stable
INSTREAM	D/E	
RIPARIAN VEGETATION	C	Stable
ECOSTATUS	C/D	

12.9 SUITABILITY AS FUTURE MONITORING SITE

12.9.1 Biotopes present

Some marginal vegetation is present in the pools for SASS sampling, with some GSM biotope present. No biotope is available in current due to no flows present. Limited overhanging vegetation is available for use by macroinvertebrates. Undercut banks, root wads, marginal aquatic and overhanging riparian vegetation is abundant for fish cover. Pools provide abundant water column cover and refugia for fish. Low habitat diversity is present and no flow depth classes are present. Extensive erosion and siltation is present and no aquatic vegetation is present. Riparian vegetation obligate species are present and dominant although the banks are fairly unmodified with respect to the riparian vegetation. An absence of substrate (rocks and cobbles), and siltation may be a limiting factor at the site (mainly muddy pool habitat). There was low habitat diversity and no flow depth classes present at the time of sampling. Habitat diversity may, however, improve with higher flows. This is not a good fish sampling site.

Component	Advantages	Disadvantages	Conf
Rip veg	Riparian alluvial habitat available, with pools Riparian obligate species present and dominant at the site Bank fairly unmodified	Erosion high at or upstream of site Access not too easy	5
Fish	Bank undercut, root wads, marginal aquatic and overhanging riparian vegetation abundant for fish cover Pools abundant for water column cover and refugia No benthic growth No NPS pollution Could serve as good spawning area during high floods with ample marginal vegetation for spawning needs of fish	Seasonal stream Low habitat diversity No flow depth classes present No flow No biotopes with substrate (i.e. cobble etc.) present Extensive erosion and siltation Local and catchment scale impacts – trampling, overgrazing, erosion (local and catchment), water abstraction and dam upstream. No instream aquatic vegetation	3.5

Component	Advantages	Disadvantages	Conf
Inverts	Some marginal vegetation in the pools present Some GSM biotope present	No biotope available in current Limited overhanging vegetation available for use by macroinvertebrates	2

12.9.2 Site suitability

The site suitability of each site was assessed and is provided in Table 12.9. All scores are out of 5 with 5 referring to very high suitability (see below).

Very High: 4.1 – 5 High: 3.1 – 4
Moderate: 2.1 – 3 Low: 1.1 – 2
Very Low: 0 – 1

Table 12.9 OSAEH 11.21: Biophysical site suitability

Site	Rip veg	Fish	Inverts	Average	Median	Max	Min	Comments
OSAEH 11.21	3.5	1.5	1	2	1.5	3.5	1	**Low** suitability for biotic component monitoring, although there are both flow and non-flow related impacts and alien vegetation invasion is not a main impact.

13 OSAEH 11.18: MODDER RIVER

13.1 SITE DESCRIPTION

Location	OSAEH 11.18	**Altitude**	1346 m
Longitude	26.57194	**Latitude**	-29.16111
EcoRegion	Highveld 11.03	**Quaternary catchment**	C52B
Water Management Area	Upper Orange	**Geomorphological zone**	Foothill

This site is bedrock-dominated with good marginal vegetation comprising sedges and overhanging vegetation. The river width varies from 2 - 15 m in places. Some sedimentation is present with filamentous algae on the rocks at the river's edge. The instream habitat consists of pools, riffles and runs, with some boulders, cobbles, gravel and sand present. The site is approximately 13 km downstream of Rustfontein Dam. Instream weirs are prevalent in the river, impacting negatively on the movement of instream biota. Bank undercutting and root wads also occur at the site. The surrounding land use consists of natural fields for grazing and agriculture.

Figure 13.1 OSAEH 11.18: Bedrock dominated riffle-run section

13.2 BIOTIC SAMPLING

The site, at the time of sampling, was dominated by extensive instream runs, with dense algal growth occurring on the substratum. Marginal vegetation was of excellent quality and quantity, with limited stones out of current biotope present. Very little sedimentation was present, with the water colour a light brown and slightly turbid. Some solid waste was observed. Cattle trampling was also observed. No exotic macrophytes were observed, as well as no exotic vegetation encroachment.

13.2.1 Fish

The fish sampling was conducted at the site during October 2010. A variety of depth classes were sampled for 50 minutes. Sampling and data analysis was followed according to Kleynhans *et al*. (2008). A summary of the site conditions during sampling is provided below. Abundance of habitat was rated as:

- 0 = absent
- 1 = rare
- 2 = sparse
- 3 = moderate

- 4 = abundant 5 = very abundant

Fish velocity-depth classes and cover present at the site

SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
4	4	1	4
Overhanging vegetation			
4	4	0	3
Undercut banks and root wads			
3	3	0	2
Substrate			
2	1	1	1
Aquatic macrophytes			
3	3	0	1
Water Column			
5	3	1	2

Habitats sampled and effort

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Electro shocker (min)	15 min	15 min	5 min	15 min

13.3 DATA AVAILABILITY

Detailed information regarding available data is provided in Table 13.1.

Table 13.1 OSAEH 11.18: Summary of data availability

Comp	Data availability	Conf
IHI	Google Earth imagery. Information from Lower Vaal Reserve study.	3
Riparian vegetation	Current Google Earth imagery of the site and site context. Data collected from field assessment during October 2010. Ecological reports and specialist assessments for this study; previous Reserve determination report SANBI floristic distribution data (2009) Literature: **Kleynhans C.J, MacKenzie J., Louw M.D.** 2007a. Module F: Riparian Vegetation Response Assessment Index in River Classification: Manual for EcoStatus Determination (version 2). Joint Water Commission and Department of Water Affairs and Forestry report. WRC Report No. TT333/08. **Low B.A., Rebello A.G.** (eds) 1998. Vegetation of South Africa, Lesotho and Swaziland**.** Department of Environmental Affairs and Tourism, Pretoria. **Mucina L. & Rutherford M.C.** (eds) 2006. Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19*. South African National Biodiversity Institute, Pretoria. **Van Wyk B. & Van Wyk P**. 2009. Field Guide to trees of Southern Africa. 12th Impression. Struik Nature Publishers, Cape Town.	4
Fish	Google Earth imagery. One site visit and fish sampling during October 2010. **Kleynhans, C.J., Louw, M.D & Moolman, J**. 2007b. Module D (Volume 2): Reference Frequency of Occurrence of Fish Species in South Africa: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry Report. WRC Report No. TT330/08. Water Research Commission, Pretoria, South Africa. **Rivers Data base** (2007): *Database on fish distribution in South African Rivers*. **Scott *et al.*** (2006): *Atlas of Southern African Freshwater Fishes*.	3
Inverts	Google Earth imagery. One site visit and fish sampling during October 2010.	1

13.4 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 13.2. Additional information on fish, macroinvertebrate and riparian vegetation reference conditions are also provided.

Table 13.2 OSAEH 11.18: Reference conditions

Comp	Reference conditions	Conf
Riparian vegetation	Grassland Biome with Highveld Alluvial Vegetation Type (Mucina & Rutherford, 2006) **Marginal Zone:** A mix of woody (mainly *Gomphostigma virgatum*) and non-woody (mainly sedge) cover, with some hydrophilic grasses and dicots is expected. **Lower Zone:** Similar to marginal zone with the dominant woody species being *Salix mucronata.* **Upper Zone including MCB:** Expect a mix of obligate and preferential woody species, and hydrophilic and terrestrial grasses.	3
Fish	Reference conditions as set for the NRHP site, C5MODDSANNA, (Kleynhans *et al.,* 2007b), which is also the OSEAH 11.18 sampling site, was used as a starting point for setting reference conditions. See Table 12.3 for a list of the reference fish species.	3
Inverts	Reference conditions are based on professional judgement and Rivers Database information. The reference SASS5 score is 220 and the ASPT is 7.	3

13.4.1 Fish

Reference conditions broadly refer to "expectations on the state of aquatic biological communities in the absence of human disturbance and pollution". In the context of this report, it refers specifically to the fish species present in a particular river reach and their frequency of occurrence under reference habitat conditions. Reference conditions as set for the National River Health Programme (NRHP) site, C5MODDSANNA, (Kleynhans *et al.,* 2007b), which is also the OSEAH 11.18 sampling site, was used as starting point for setting reference conditions.

Professional opinion and experience; sampling; and habitat and site observations were further used to obtain a derived FROC from the reference FROC, based on the species habitat and condition preferences and tolerances (Table 13.3).

Six indigenous fish species are expected under reference conditions and are listed in Table 13.3. An exotic fish species *Cyprinus carpio* is also listed for this system.

Table 13.3 OSAEH 11.18: Reference fish species

Expected Reference and Habitat derived FROC of fish at OSAEH 11.18 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Labeobarbus aeneus	Smallmouth yellowfish	BAEN	1	1
Barbus anoplus	Chubbyhead barb	BANO	1	1
Labeobarbus kimberleyensis	Largemouth yellowfish	BKIM	3	1
Clarias gariepinus	Sharptooth catfish	CGAR	1	1
Labeo capensis	Orange River labeo	LCAP	1	1
Labeo umbratus	Moggel	LUMB	1	1
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%) 3 = present at about >25 - 50 % of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)				
ALIEN AND INVASIVE SPECIES				
Cyprinus carpio	Common Carp	CCAR		

13.4.2 Macroinvertebrates

Macroinvertebrate taxa expected under reference conditions include:

Hydropsychidae (>2 spp.), Baetidae (>2 spp.), Tricorythidae, Elmidae/ Dryopidae, Atyidae, Leptophlebiidae, Hydracarina, Simuliidae, Coenagrionidae, Naucoridae, Hydroptilidae, Tipulidae, Corbiculidae, Caenidae, Gerridae, Veliidae/ Mesoveliidae, Dytiscidae/ Noteridae, Gyrinidae, Ceratopogonidae, Hydrophilidae, Turbellaria, Gomphidae, Libellulidae, Pleidae, Leptoceridae, Aeshnidae, Hydraenidae, Notonectidae, Muscidae, Syrphidae, Physidae, Planorbidae and Hirudinea.

13.5 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information provided with this report.

13.5.1 Index of Habitat Integrity (IIHI: C, 68.1%; RIHI: C, 66.7%)

The IIHI is mostly due to poor bed conditions, with elevated levels of sediment and benthic growth (also associated with elevated nutrients at the site due to close upstream proximity of weir and high density cattle), and altered flow regimes with reduced base flows and flooding. Longitudinal connectivity also scored poorly due to impoundments. The RIHI is a C with the main impacts being poor bank conditions due to a high degree of erosion and substrate exposure, with trampling pressure exacerbating the situation. Reduced base flows and small floods facilitate an increase in marginal and lower zone vegetation.

13.5.2 Diatoms (C EC)

The assessment is based on single sample taken during the current assessment. This site was critically polluted with organic pollution levels being high and organically bound nitrogen levels being periodically elevated. From the diatom community it is evident that agricultural runoff and fertilizer use is impacting the site.

13.5.3 Fish (C EC, 67.2%)

All of the fish species (6 out of 6) expected under reference conditions are still expected to be present under the present conditions at this site and in the river.

Note: Some species (*B. aeneus* and *L. capensis*) were sampled at an increased/improved FROC from reference conditions as they were sampled in high densities at the site, indicating that habitat conditions are suitable for species with a preference for a variety of flow depth classes, and species which are moderately intolerant to no flow conditions. The FROC of *B. kimberleyensis* was reduced due to flow modification and lower base flows resulting in a loss of FD habitat.

Good spawning habitat is present for spawning during high floods, and pools are present as refugia and nursery area, after floods. Reduced base flows and loss of longitudinal connectivity, due to the impacts as discussed in this document, are causes of concern for the fish population and their successful migration, spawning and recruitment.

The presence of carp, which can prey on fish eggs and causes bio-turbation, may also negatively impact on the fish species present in the system.

The FROC of *C. gariepinus* and *L. umbratus* (quiet water benthic species) is expected to be low due to the stream being dominantly bedrock with fast flow.

The main present impact on the fish is decreased flows and the loss of water column in FD habitat as cover. Substrate (rocks and cobbles) as cover is also sparse.

Main impacts on the fish: A large dam upstream, smaller weirs and water abstraction are the main reasons for the flow modification i.e. reduced dry season base flow, as experienced during the survey and a reduced FROC for *B. kimberleyensis*.

13.5.4 Macroinvertebrates (D EC, 57.3%)

Macroinvertebrates were sampled using the standard SASS5 method. Habitat available was Stones in current (SIC), Stones out of current (SOOC), Marginal vegetation in current (MVIC), Marginal vegetation out of current (MVOC), Gravel sand and mud (GSM). No Aquatic vegetation (AV) was present at the site. For list of families present please refer to the MIRAI.

SASS results:

Oct 2010: SASS5 score: 95 No of Taxa: 21 ASPT: 4.52

Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Hydropsychidae >2spp, Pyralidae, Tricorhythidae, Leptophlebiidae, Philopotamidae and Chlorocyphidae.

13.5.5 Riparian vegetation (B EC, 82.3%)

The assessment was done using VEGRAI level 4.

Marginal Zone:

Bedrock controlled with riffle/runs and pools; some cobble but mostly sheet rock. Some alluvial deposits (fine alluvium) and well vegetated. *Gomphostigma virgatum, C. marginatus* and *Cyclosorus interruptus* dominate the open and bedrock areas. *Salix mucronata* common with overhang, rooted where alluvia are consolidated.

Lower Zone:

As with the marginal zone, but with extensive high density and cover areas of *Salix mucronata* along lateral consolidated alluvial bars.

Upper Zone:

Characterised by open sheet rock, highly exposed and eroded due to high grazing and trampling pressure and scour of sediments due to lack of vegetated cover. Alluvial terraces dominated by grasses with woody patches, mainly *Searsia pyroides, Acacia karoo* and *Lycium hirsutum*.

MCB:

Dominated by woody vegetation (as Upper zone) with terrestrial grasses in between.

13.5.6 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 13.4.

Table 13.4 OSAEH 11.18: Causes and sources

	PES	Causes	Sources	F/NF
Rip veg	B	Reduced cover of indigenous riparian obligate species.	Moderate to high trampling and grazing pressure with bank destabilization and erosion, also minimal wood cutting.	NF
		Altered species composition.	Small impact of alien vegetation (5% annuals, 5% perennial mainly *Eucalyptus camuldensis*).	
		Altered species composition.	Reduced maintenance flows and small floods promote and increase in woody vegetation and sedges in the marginal and lower zone, especially when coupled with high grazing pressure.	F

	PES	Causes	Sources	F/NF
Fish	C	Decreased species diversity and abundance due to presence of carp.	Presence of alien species (carp) introduced for aquaculture and angling.	NF
		Enrichment.	Cattle farming, trampling – erosion and excrement upstream.	
		Presence of dams and weirs as migration barriers (breeding, feeding and dispersal), also causing loss of habitat of some species (inundation).	Dam and other smaller weirs in area.	
		Loss of mainly FD habitat and other flow depth classes to lesser extent as a result of flow modification (especially during naturally low flow periods).	Large dam, smaller weirs and water abstraction for farming and irrigation and urbanization upstream.	F
		Lower breeding success and recruitment for fish = lower FROC.	Lower, less and/or no natural flushes and smaller floods. Flow modification due to dam etc.	
		Loss of species diversity or numbers due to loss of habitat diversity due to lower flows.	Flow modification due to dam etc.	
		Loss of habitat with substrate (cobbles and rock) due to lower than natural flows.	Flow modification due to dam etc.	
Inverts	D	Increased sedimentation.	Agriculture.	F
		Poor water quality and associated benthic growth.		NF

13.6 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 13.5.

Table 13.5 OSAEH 11.18: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Rip veg	B	Stable			Vegetation at the site has reached stable reaction to current impacts	3
Fish	C	Stable			The site was surveyed during the dry season base flow period (low flow), and certain fish species with a moderate intolerance to no flows were sampled in high numbers. It is expected that fish will use the pools for refuge areas, and all of the expected species are still expected to be present. Spawning habitat is present, and can be utilized by fish during higher flows or floods. The PES is a C, and with the current flow regulation and modification it will not improve, but will remain stable under current conditions, as the fish seem to have adapted to current conditions.	3
Inverts	D	Stable			The macroinvertebrates have already reacted to the current conditions.	1

13.7 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 13.6. The Instream EC is a C (63.2%).

Table 13.6 OSAEH 11.18: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	5	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	4	90		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	4	90		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	70		
FISH ECOLOGICAL CATEGORY	16	350	**67.2**	**C**
MACROINVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	3	100		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	3	100		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	70		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**8**	270	**57.3**	**D**
INSTREAM ECOLOGICAL CATEGORY (Excl confidence)		620	**62.5**	**C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	3	0.60	40.32	
Confidence rating for **macroinvertebrate** information	2	0.40	22.92	
	5	1.00	63.24	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**C**	

To determine the EcoStatus, the VEGRAI EC and confidence is included in the EcoStatus assessment index (Table 13.7). The EcoStatus EC is a C.

Table 13.7 OSAEH 11.18: Instream EC

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**82.3**	**B**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	2.6	0.47	29.90
Confidence rating for riparian vegetation zone information	2.9	0.53	43.39
	5.5	1.00	73.29
ECOSTATUS	**EC**		**C**

13.8 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised in Table 13.8.

Table 13.8 OSAEH 11.18: EcoClassification results

Driver Components	PES	Trend
IHI: INSTREAM	C	
IHI: RIPARIAN	C	
DIATOMS (WQ)	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	D	Stable
INSTREAM	C	
RIPARIAN VEGETATION	B	Stable
ECOSTATUS	C	

13.9 SUITABILITY AS FUTURE MONITORING SITE

13.9.1 Biotopes present

A diversity of flow velocities is present for SASS sampling. Biotopes present include SIC, marginal vegetation in- and out of current as well as GSM. The site is bedrock dominated which reduces the amount of instream habitat for macroinvertebrates. Sedimentation occurs as well as turbid waters. The river is perennial with good fish habitat diversity and cover. Bank undercutting, instream and marginal aquatic and overhanging riparian vegetation are abundant for fish cover. Pools occur frequently which serve as water column cover and refugia for fish. The FD fish habitat is rare or sparse at low base flows and will be more abundant during high base flows. Instream substrate, for example cobbles, is sparse. The site is situated downstream of a bridge and a weir. Trampling, overgrazing, urbanization, erosion and abstraction are some examples of local and catchment scale impacts. Riparian vegetation obligate species are present (rheophytes, heliophytes and bank species) and are also dominant at the site.

Component	Advantages	Disadvantages	Conf
Rip veg	Riparian alluvial and bedrock habitats available, with pools Riparian obligate species present (rheophytes, helophytes and bank species) and dominant at the site	Erosion and scour high at or upstream of site Close proximity to bridge and weir upstream	5
Fish	Perennial stream Good habitat diversity and cover Bank undercut; instream and marginal aquatic and overhanging riparian veg. abundant for fish cover Pools common for water column cover and refugia Minimal benthic growth (thin film) – seems natural No non point source pollution Could serve as good spawning area during high floods with ample marginal vegetation for spawning needs of fish. Preferred habitat for rare species – BKIM and	FD rare or sparse at low base flow, will be more abundant during high base flow Substrate for cover is sparse (rocks and cobbles etc.) Erosion and abstraction upstream Flow modification due to dam and weirs upstream – decrease in base flows and floods, and impact on seasonality of smaller floods. Site below bridge and weir. Local and catchment scale impacts –	3.5

Component	Advantages	Disadvantages	Conf
	ASCL	trampling, overgrazing, erosion (local and catchment), water abstraction, urbanization, and dam upstream.	
Inverts	Stones biotope present Diversity of flow velocities Marginal vegetation in and out of current GSM biotope present	Limited SIC and SOOC biotope Site dominated by bedrock High sedimentation High turbidity	3

13.9.2 Site suitability

The site suitability of each site was assessed and is provided in Table 13.9. All scores are out of 5 with 5 referring to very high suitability (see below).

Very High: 4.1 – 5 High: 3.1 – 4
Moderate: 2.1 – 3 Low: 1.1 – 2
Very Low: 0 – 1

Table 13.9 OSAEH 11.18: Biophysical site suitability

Site	Rip veg	Fish	Inverts	Average	Median	Max	Min	Comments
OSAEH 11.18	3.5	4	2	3.17	3.5	4	2	**High** suitability for biotic component monitoring. There are both flow and non-flow related impacts and alien vegetation invasion is not a main impact.

14 OSAEH 26.10: RIET RIVER

14.1 SITE DESCRIPTION

Location	OSAEH 26.10	**Altitude**	1273
Longitude	25.70805	**Latitude**	-29.57528
EcoRegion	Nama Karoo 26.03	**Quaternary catchment**	C51F
Water Management Area	Upper Orange	**Geomorphological zone**	Foothill

The site mainly constitutes bedrock and boulder substrate and no flow was present at the time of sampling. Large pools were present with abundant marginal vegetation consisting of sedges and reeds. GSM biotope occurs at the site. Riparian vegetation consists of trees, shrubs, grasses, sedges and reeds. No large dams occur upstream but small weirs are present upstream. Surrounding land use is natural fields for grazing and agriculture.

Figure 14.1 OSAEH 26.10: Large deep pool below bridge with bedrock and rocks, as well as marginal veg. for cover

14.2 BIOTIC SAMPLING

At the time of sampling no flow was present at the site. Large pools with bedrock and boulder substrate were present for sampling. Moderate sedimentation occurred and no odours were detected. No exotic macrophytes or vegetation encroachment observed. Benthic algal growth and filamentous algae were present.

14.2.1 Fish

The fish sampling was conducted at the site during October 2010. There was no flow at the time of sampling, but very large deep pools (>1km long) occurred at the site (refugia). The pools were sampled in shallow to 1.5 m deep water. Fish were sampled for 45 minutes. Sampling and data analysis was followed according to Kleynhans (2007). A summary of the site conditions during sampling is provided below. Abundance of habitat was rated as:

- 0 = absent
- 1 = rare
- 2 = sparse
- 3 = moderate
- 4 = abundant
- 5 = very abundant

Fish velocity-depth classes and cover present at the site

	Pools
	5
Overhanging vegetation	
	5
Undercut banks and root wads	
	3
Substrate	
	5
Aquatic macrophytes	
	1
Water Column	
	5

14.3 DATA AVAILABILITY

Detailed information regarding available data is provided in Table 14.1.

Table 14.1 OSAEH 26.10: Summary of data availability

Comp	Data availability	Conf
IHI	Google Earth imagery. Information from Lower Vaal Reserve study.	3
Riparian vegetation	Current Google Earth imagery of the site and site context. Data collected from field assessment during October 2010. Ecological reports and specialist assessments for this study; previous Reserve determination report SANBI floristic distribution data (2009) Literature: **Kleynhans C.J, MacKenzie J., Louw M.D.** 2007a. Module F: Riparian Vegetation Response Assessment Index in River Classification: Manual for EcoStatus Determination (version 2). Joint Water Commission and Department of Water Affairs and Forestry report. WRC Report No. TT333/08. **Low B.A., Rebello A.G.** (eds) 1998. Vegetation of South Africa, Lesotho and Swaziland**.** Department of Environmental Affairs and Tourism, Pretoria. **Mucina L. & Rutherford M.C.** (eds) 2006. Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19*. South African National Biodiversity Institute, Pretoria. **Van Wyk B. & Van Wyk P**. 2009. Field Guide to trees of Southern Africa. 12th Impression. Struik Nature Publishers, Cape Town.	4
Fish	Google Earth imagery. One site visit and fish sampling during October 2010. **Kleynhans, C.J., Louw, M.D & Moolman, J**. 2007b. Module D (Volume 2): Reference Frequency of Occurrence of Fish Species in South Africa: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry Report. WRC Report No. TT330/08. Water Research Commission, Pretoria, South Africa. **Rivers Data base** (2007): *Database on fish distribution in South African Rivers*. **Scott *et al.*** (2006): *Atlas of Southern African Freshwater Fishes*.	3
Inverts	Google Earth imagery. One site visit and fish sampling during October 2010.	1

14.4 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 14.2. Additional information on fish, macroinvertebrate and riparian vegetation reference conditions are also provided.

Table 14.2 OSAEH 26.10: Reference conditions

Comp	Reference conditions	Conf
Riparian vegetation	Grassland Biome with Xhariep Karroid Grassland Vegetation Type (Mucina & Rutherford, 2006) **Marginal Zone:** Present state close to reference, but with higher flows and reduced reed cover. *Salix mucronata* density also likely to be less with more natural flood disturbance. Vegetation consists of various components: 1) Narrow high density *Phragmites australis* along deep pools. 2) Open sheet rock or damp mud where the river has stopped flowing, with some grazed *Cynodon dactylon.* 3) Alluvial deposits with dense and tall stands of *Salix mucronata.* 4) *Schoenoplectus* species or *Gomphostigma virgatum* associated with sunny areas with some bedrock. Lower Zone: Similar to marginal zone, with more extensive *Salix mucronata* and *Schoenoplectus* species. Upper Zone including MCB: Grassland and woody mix, with high proportions of open bedrock expected.	3.5
Fish	Reference conditions as set for the NRHP site, C5RIETIFR03, (Kleynhans *et al.,* 2007b), which is also the OSEAH 26.10 sampling site, was used as a starting point for setting reference conditions. See Table 13.3 for a list of the reference fish species.	3
Inverts	Reference conditions are based on professional judgement and Rivers Database information. The reference SASS5 score is 200 and the ASPT is 6.5.	2

14.4.1 Fish

Reference conditions broadly refer to “expectations on the state of aquatic biological communities in the absence of human disturbance and pollution”. In the context of this report, it refers specifically to the fish species present in a particular river reach and their frequency of occurrence under reference habitat conditions. Reference conditions as set for the NRHP site, C5RIETIFR03, (Kleynhans *et al.,* 2007b), which is also the OSEAH 26.10 sampling site, was used as starting point for setting reference conditions.

Professional opinion and experience; sampling; and habitat and site observations were further used to obtain a derived FROC from the reference FROC, based on the species habitat and condition preferences and tolerances (Table 14.3).

Eight indigenous fish species are expected under reference conditions and are listed in Table 14.3. An exotic fish species *Cyprinus carpio* is also listed for this system

Table 14.3 OSAEH 26.10: Reference fish species

Expected Reference and Habitat derived FROC of fish at OSAEH 26.10 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Labeobarbus aeneus	Smallmouth yellowfish	BAEN	1	1
Barbus anoplus	Chubbyhead barb	BANO	1	1
Labeobarbus kimberleyensis	Largemouth yellowfish	BKIM	3	1
Clarias gariepinus	Sharptooth catfish	CGAR	1	1
Labeo capensis	Orange River labeo	LCAP	1	1
Labeo umbratus	Moggel	LUMB	3	3
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	1	1
Tilapia sparrmanii	Banded tilapia	TSPA	1	1
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%) 3 = present at about >25 - 50 % of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)				
ALIEN AND INVASIVE SPECIES				

Expected Reference and Habitat derived FROC of fish at OSAEH 26.10 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Cyprinus carpio	Common Carp	CCAR		

14.4.2 Macroinvertebrates

Macroinvertebrate taxa expected under reference conditions include:
Hydropsychidae (>2spp.), Baetidae (>2 spp.), Tricorythidae, Elmidae/ Dryopidae, Atyidae, Leptophlebiidae, Hydracarina, Simuliidae, Coenagrionidae, Naucoridae, Hydroptilidae, Tipulidae, Corbiculidae, Caenidae, Gerridae, Veliidae/ M...veliidae, Dytiscidae/ Noteridae, Gyrinidae, Ceratopogonidae, Porifera, Hydrophilidae, Turbellaria, Potamonautidae, Corixidae, Chironomidae, Sphaeriidae, Oligochaeta, Tabanidae, Gomphidae, Pleidae, Libellulidae, Ancylidae, Leptoceridae, Chlorocyphidae, Aeshnidae, Notonectidae, Culicidae, Psychodidae, Muscidae, Belostomatidae, Lymnaeidae, Planorbidae, and Hirudinea.

14.5 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information provided with this report.

14.5.1 Index of Habitat Integrity (IIHI: C, 72.7%; RIHI: B/C, 77.9%)

The IIHI is a C and is mostly due to poor bed conditions, with elevated levels of sediment and benthic growth (also associated with elevated nutrients at the site), and to a less extent altered flow regimes with reduced base flows and flooding, and increased occurrence of zero flows. The RIHI is a B/C with the main impacts being poorer bank conditions due to a higher substrate exposure, with trampling pressure exacerbating the situation. Reduced base flows and small floods facilitate an increase in marginal and lower zone vegetation and flow regulation promoted reed expansion and density.

14.5.2 Diatoms (C EC)

The assessment is based on single sample taken during the current assessment. Nutrient levels are elevated at times while organic loading is moderate. The site is generally moderately polluted.

14.5.3 Fish (C EC, 72.9%)

All of the fish species (8 out of 8) expected under reference conditions are still expected to be present under the present conditions at this site and in the river.

Note: *L. capensis* P was sampled at an increased/improved FROC from reference conditions as it was sampled in high densities at the site, indicating that habitat conditions are suitable for species with a preference for a variety of flow depth classes, and species which are moderately intolerant to no flow conditions (*L. aeneus*, *L. kimberleyensis*, and *L. capensis*). The FROC of *L. kimberleyensis* was reduced due to flow modification and lower base flows resulting in a loss of FD habitat. No flow at time of sampling.

Very large pools were present and all the species will be able to survive in these pools over extended periods of time. The pools serve as cover and refugia.

Good spawning habitat is present for spawning during high floods, and pools are present as refugia and nursery area, after floods. Reduced base flows and loss of longitudinal connectivity, due to the impacts as discussed in this document, may be causes of concern for the fish population and their successful migration, spawning and recruitment.

The presence of carp, which can prey on fish eggs and causes bio-turbation, may also negatively impact on the fish species present in the system.

The FROC of *C. gariepinus*, *L. umbratus* (quiet water benthic species), *B. anoplus*, *P. philander* and *T. sparrmanii* is unchanged from reference as these species are moderately tolerant to tolerant to no-flow conditions. Habitat diversity is also high in terms of their different habitat preferences (Cover – water column, bedrock, rocks and cobbles, bank undercut, marginal aquatic veg. and tree overhang etc.)

The main present impact on the fish is decreased flows and the loss of flow and especially FD habitat, most probably due to water abstraction

Main impacts on the fish: Smaller weirs and water abstraction upstream are the main reasons for the flow modification i.e. reduced dry season base flow, as experienced during the survey and a reduced FROC for *L. kimberleyensis*.

14.5.4 Macroinvertebrates (C EC, 65.4%)

Macroinvertebrates were sampled using the standard SASS5 method. There was no flow during sampling time, a pool was sampled. Habitat available was Stones out of current (SOOC), Marginal vegetation out of current (MVOC), Gravel sand and mud (GSM). No Aquatic vegetation (AV) was sampled at the site. For list of families present in the sample please refer to the MIRAI.

SASS results:

Oct 2010: SASS5 score: 74 No of Taxa: 16 ASPT: 4.6

Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Hydropsychidae (>2 spp), Baetidae (>2 spp), Aeshnidae, Chlorocyphidae, Elmidae, Gerridae, Leptophlebidae, Tricorythidae, and Vellidae/ Mesovellidae. Most of cobble dwelling expected taxa were missing during the time of sampling despite moderate abundance of stones habitat.

14.5.5 Riparian vegetation (B EC, 83.5 %)

The assessment was done using VEGRAI level 4.

Marginal Zone:

Various vegetation components exist:

1) Narrow high density *Phragmites australis* along deep pools.
2) Open sheet rock or damp mud where the river has stopped flowing, with some grazed *C. dactylon*.
3) Alluvial deposits with dense and tall stands of *S. mucronata*.
4) *Schoenoplectus* species or *G. virgatum* associated with sunny areas with some bedrock.

Lower Zone:

Similar to marginal zone components 1 and 3, with dominant and extensive component 4 above; also *Agrostis lachnantha* (a hydrophilic grass).

Upper Zone:

Dry: RB - is an alluvial terrace with *Searsia pyroides* and *Lycium* sp as dominants mixed with terrestrial grasses; LB - open sheet rock with some fine sediments, not well vegetated.

MCB:

Alluvial; woody and grass mix, with *Diospyros lycioides* and terrestrial grasses dominant.

14.5.6 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 14.4.

Table 14.4 OSAEH 26.10: Causes and sources

14.6 PES TREND

	PES	Causes	Sources	F/NF
Rip veg	B	Reduced cover of indigenous riparian obligate species, mainly grasses and some woody species.	Moderate to high trampling and grazing pressure (sheep mainly) with bank destabilization in places.	NF
		Altered species composition.	Small impact of alien vegetation (5% annuals, 5% perennial mainly *Populus alba*).	
		Increased vegetation cover of sedges and reeds.	Flow regulation and reduced flooding disturbance facilitates an increase in reed and sedge cover and density in the marginal and lower zone.	F
Fish	C	Loss of all flow classes and mainly FD habitat as a result of flow modification (especially during naturally low flow periods).	Smaller weirs and water abstraction for farming and irrigation upstream.	F
		Lower breeding success and recruitment for fish = lower FROC.	Lower, less and/or no natural flushes and smaller floods. Flow modification due to smaller weirs and water abstraction for farming and irrigation upstream.	
		Loss of species diversity or numbers due to loss of habitat diversity due to lower flows.	Flow modification due to smaller weirs and water abstraction for farming and irrigation upstream.	
		Loss of habitat with substrate (cobbles and rock), and water column in FD due to lower than natural flows.		
		Loss of longitudinal connectivity for migration.		
		Decreased species diversity and abundance due to presence of carp.	Presence of alien species (carp) introduced for aquaculture and angling.	NF
		Enrichment.	Agriculture upstream.	
		Presence of dams and weirs as migration barriers (breeding, feeding and dispersal), also causing loss of habitat of some species (inundation).	Dam downstream and other smaller weirs in area.	
Inverts	C	No flow. Sedimentation and bank erosion.	Agriculture	F
		Poor water quality and associated benthic growth.		NF

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 14.5.

Table 14.5 OSAEH 26.10: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Rip veg	B	Stable			Vegetation at the site has reached stable reaction to current impacts	3
Fish	C	Stable			The site was surveyed during the dry season base flow period (low flow), and certain fish species with a moderate intolerance to no flows were sampled in high numbers. It is expected that fish will use the pools for refuge areas, and all of the expected species are still expected to be present. Spawning habitat is present, and can be utilized by fish during higher flows or floods. The PES is a C, and with the current flow regulation and modification it will	3

	PES	Trend	Trend PES	Time	Reasons	Conf
					not improve, but will remain stable under current conditions, as the fish seem to have adapted to current conditions. Although no flow was observed during the dry season base flow survey, it is expected that the extremely large and deep pools will sustain the fish population in this area for extended periods of time	
Inverts	C	Stable			The macroinvertebrates have already reacted to the current conditions.	1

14.7 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 14.6. The Instream EC is a C (70.4%).

Table 14.6 OSAEH 26.10: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	3	90		
2.What is the natural diversity of **fish** species with a preference for different cover types	3	90		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	4	100		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	90		
FISH ECOLOGICAL CATEGORY	13	370	**72.9**	**C**
MACROINVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	2	100		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	2	100		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	100		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**6**	300	**65.4**	**C**
INSTREAM ECOLOGICAL CATEGORY (Excl confidence)		670	**69.5**	**C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	4	0.67	48.60	
Confidence rating for **macroinvertebrate** information	2	0.33	21.80	
	6	1.00	70.40	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**C**	

To determine the EcoStatus, the VEGRAI EC and confidence is included in the EcoStatus assessment index (Table 14.7). The EcoStatus EC is a C.

Table 14.7 OSAEH 26.10: Instream EC

RIPARIAN VEGETATION	EC %	EC
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**83.5**	**B**

ECOSTATUS	Confidence rating	Proportions	Modified weights
Confidence rating for instream biological information	3.33	0.54	38.26
Confidence rating for riparian vegetation zone information	2.8	0.46	38.12
	6.13	1.00	76.38
ECOSTATUS	**EC**		**C**

14.8 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised in Table 14.8.

Table 14.8 OSAEH 26.10: EcoClassification results

Driver Components	PES	Trend
IHI: INSTREAM	C	
IHI: RIPARIAN	B/C	
DIATOMS (WQ)	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	B	Stable
ECOSTATUS	**C**	

14.9 SUITABILITY AS FUTURE MONITORING SITE

14.9.1 Biotopes present

A moderate quality and quantity of SOOC biotope is available for SASS sampling. Marginal vegetation out of current is also available. No instream biotopes are available for SASS sampling. Good habitat diversity and cover for all expected fish species is available. Undercut banks, aquatic marginal and overhanging vegetation, water column and substrate provide abundant cover for fish. Pools are abundant for water column cover for fish. Erosion and abstraction upstream, instream weirs modify flows and thus instream habitat. Site is situated downstream of a bridge. Benthic growth due to nutrient enrichment impacts negatively on the available habitat. Riparian vegetation obligate species are present and dominant at the site.

Component	Advantages	Disadvantages	Conf
Rip veg	Riparian alluvial and bedrock habitats available, with pools Riparian obligate species present (rheophytes, helophytes and bank species) and dominant at the	Close proximity to bridge upstream and tributary downstream	5

Component	Advantages	Disadvantages	Conf
	site		
Fish	Good habitat diversity and cover for all expected species (esp. during flows) Bank undercut; marginal aquatic, overhanging riparian veg., water column (pools) and substrate, abundant for fish cover Pools abundant for water column cover and refugia No non-point source pollution observed Could serve as good spawning area during high floods with ample marginal veg. and substrate for spawning needs of fish	Semi-perennial river changed to seasonal river due to water abstraction No flow during dry season base flow – low flow season Erosion and abstraction upstream Flow modification due to weirs and abstraction upstream – decrease in base flows and floods, and impact on seasonality of smaller floods Site below bridge Local and catchment scale impacts – erosion in catchment, weirs and water abstraction, upstream Benthic growth - enrichment Deeper areas of pool are non-wadeable for sampling	3.5
Inverts	Moderate quality and quantity of stones out of current biotope present Marginal vegetation out of current available	No SIC, and MVIC biotopes present Limited GSM biotope present No overhanging vegetation in current available	1.5

14.9.2 Site suitability

The site suitability of each site was assessed and is provided in Table 14.9. All scores are out of 5 with 5 referring to very high suitability (see below).

Very High: 4.1 – 5 High: 3.1 – 4
Moderate: 2.1 – 3 Low: 1.1 – 2
Very Low: 0 – 1

Table 14.9 OSAEH 29.10: Biophysical site suitability

Site	Rip veg	Fish	Inverts	Average	Median	Max	Min	Comments
OSAEH 26.10	4	4	2.5	3.5	4	4	2.5	**High** suitability for biotic component monitoring. There are both flow and non-flow related impacts and alien vegetation invasion is not a main impact.

15 OSAEH 29.5: LILYDALE LODGE (RIET RIVER)

EWR 19 was assessed as part of the Lower Vaal Reserve study, and the results are provided in the summary report (Technical report 1). The results provided below are based on the assessment undertaken during October 2010 as part of this study.

15.1 SITE DESCRIPTION

Location	OSAEH 29.5	**Altitude**	1107 m
Longitude	24.075780	**Latitude**	-28.707580
EcoRegion	Southern/Central Kalahari 29.02	**Quaternary catchment**	C51L
Water Management Area	Upper Orange	**Geomorphological zone**	Lower Foothills

OSAEH 29.5 is situated in the lower reaches of the Riet River below Ritchie and lies within Mokala National Park. The catchment area is dominated by irrigated agriculture. The dominant substrate at the site is bedrock and boulder. Cobble, boulder and rocky substrate is very abundant for cover for aquatic biota. Adequate flow was present at the time of sampling. Large pools for fish refugia were present with abundant marginal vegetation consisting of sedges and reeds and GSM biotope occurs at the site. Good habitat diversity for bio-monitoring purposes is present. Riparian vegetation consists of trees, shrubs, grasses, sedges and reeds. No large dams occur upstream but small weirs are present. The surrounding land use is natural veld for the game reserve.

Figure 15.1 OSAEH 29.5: Bedrock with boulder and rock substrate and good habitat diversity

15.2 BIOTIC SAMPLING

At the time of sampling, adequate flow was present at the site. Abundant reeds, sedges, cobbles, boulders and marginal vegetation (reeds and sedges) occur at the site. Filamentous and benthic algae and the exotic macrophyte, *Azolla,* were also observed. No local erosion was present however erosion upstream and downstream of the site does occur. Moderate sedimentation was present on the substratum. No odours were detected.

15.2.1 Fish

The fish sampling was conducted at the site during October 2010. A variety of depth classes were sampled for 45 minutes. Sampling and data analysis was followed according to Kleynhans *et al*. (2008). A summary of the site conditions during sampling is provided below. Abundance of habitat was rated as:

- 0 = absent 1 = rare
- 2 = sparse 3 = moderate
- 4 = abundant 5 = very abundant

Fish velocity-depth classes and cover present at the site

SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
4	4	3	2
Overhanging vegetation			
2	3	0	0
Undercut banks and root wads			
0	0	0	0
Substrate			
5	5	5	5
Aquatic macrophytes			
5	5	0	0
Water Column			
5	5	5	5

Habitats sampled and effort

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Electro shocker (min)	15 min	15 min	10 min	5 min

15.3 DATA AVAILABILITY

Detailed information regarding available data is provided in Table 15.1.

Table 15.1 OSAEH 29.5: Summary of data availability

Comp	Data availability	Conf
IHI	Google Earth imagery. Information from Lower Vaal Reserve study.	3
Riparian vegetation	Current Google Earth imagery of the site and site context. Data collected from field assessment during October 2010. Ecological reports and specialist assessments for this study; previous Reserve determination report SANBI floristic distribution data (2009) Literature: **Kleynhans C.J, MacKenzie J., Louw M.D.** 2007a. Module F: Riparian Vegetation Response Assessment Index in River Classification: Manual for EcoStatus Determination (version 2). Joint Water Commission and Department of Water Affairs and Forestry report. WRC Report No. TT333/08. **Low B.A., Rebello A.G.** (eds) 1998. Vegetation of South Africa, Lesotho and Swaziland**.** Department of Environmental Affairs and Tourism, Pretoria. **Mucina L. & Rutherford M.C.** (eds) 2006. Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19*. South African National Biodiversity Institute, Pretoria. **Van Wyk B. & Van Wyk P**. 2009. Field Guide to trees of Southern Africa. 12th Impression. Struik Nature Publishers, Cape Town.	4
Fish	Google Earth imagery. One site visit and fish sampling during October 2010. **Kleynhans, C.J., Louw, M.D & Moolman, J**. 2007b. Module D (Volume 2): Reference Frequency of Occurrence of Fish Species in South Africa: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry Report. WRC Report No. TT330/08. Water Research Commission, Pretoria, South Africa. **Rivers Data base** (2007): *Database on fish distribution in South African Rivers*. **Scott *et al.*** (2006): *Atlas of Southern African Freshwater Fishes*.	3

Inverts	Google Earth imagery. One site visit and fish sampling during October 2010.	1

15.4 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 15.2. Additional information on fish, macroinvertebrate and riparian vegetation reference conditions are also provided.

Table 15.2 OSAEH 29.5: Reference conditions

Comp	Reference conditions	Conf
Riparian vegetation	Savanna Biome, Eastern Kalahari Bushveld Bioregion, and Kimberley Thornveld Vegetation Type (Mucina & Rutherford, 2006). **Marginal Zone:** Present state close to reference, with various vegetation components: 1) *Gomphostigma virgatum* and *Cyperus marginatus* where riffle and cobble/boulder occur (not dominant). 2) High density *P. australis*. 3) Aquatic vegetation in pools with *Ceratophyllum* and *Potemogeton* dominant. 4) *Juncus* sp and *Schoenoplectus* sp with hydrophylic grasses along boulder bars where reeds do not occur. Lower Zone: Similar to marginal zone, with more grass cover. Upper Zone including MCB: Mainly woody and grass mix, with small proportion of reeds in places.	3
Fish	Reference conditions as set for the NRHP site, C5RIETIFR01, (Kleynhans *et al.,* 2007b), which is also the OSEAH 29.5 sampling site, was used as a starting point for setting reference conditions. See Table 14.3 for a list of the reference fish species.	3
Inverts	Reference conditions are based on professional judgement and Rivers Database information. The reference SASS5 score is 200 and the ASPT is 6.5.	2

15.4.1 Fish

Reference conditions broadly refer to “expectations on the state of aquatic biological communities in the absence of human disturbance and pollution”. In the context of this report, it refers specifically to the fish species present in a particular river reach and their frequency of occurrence under reference habitat conditions. Reference conditions as set for the NRHP site, C5RIETIFR01, (Kleynhans *et al.,* 2007b), which is also the OSEAH 29.5 sampling site, was used as starting point for setting reference conditions.

Professional opinion and experience; sampling; and habitat and site observations were further used to obtain a derived FROC from the reference FROC, based on the species habitat and condition preferences and tolerances (Table 15.3).

Eight indigenous fish species are expected under reference conditions and are listed in Table 15.3. An exotic fish species *Cyprinus carpio* is also listed for this system.

Table 15.3 OSAEH 29.5: Reference fish species

Expected Reference and Habitat derived FROC of fish at OSAEH 29.5 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Austroglanis sclateri	Rock catfish	ASCL	3	1
Labeobarbus aeneus	Smallmouth yellowfish	BAEN	1	1
Labeobarbus kimberleyensis	Largemouth yellowfish	BKIM	1	1
Clarias gariepinus	Sharptooth catfish	CGAR	1	1
Labeo capensis	Orange River labeo	LCAP	1	1

Expected Reference and Habitat derived FROC of fish at OSAEH 29.5 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Labeo umbratus	Moggel	LUMB	3	1
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	1	1
Tilapia sparrmanii	Banded tilapia	TSPA	1	1
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%) 3 = present at about >25 - 50 % of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)				
ALIEN AND INVASIVE SPECIES				
Cyprinus carpio	Common Carp	CCAR		

15.4.2 Macroinvertebrates

Macroinvertebrate taxa expected under reference conditions include:
Perlidae, Hydropsychidae (>2 spp.), Baetidae (>2 spp.), Tricorythidae, Elmidae/ Dryopidae, Leptophlebiidae, Hydracarina, Simuliidae, Coenagrionidae, Naucoridae, Corbiculidae, Caenidae, Gerridae, Veliidae, Dytiscidae/ Noteridae, Gyrinidae, Ceratopogonidae, Porifera, Hydrophilidae, Turbellaria, Potamonautidae, Corixidae, Chironomidae and Oligochaeta.

15.5 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information provided with this report.

15.5.1 Index of Habitat Integrity (IIHI: B/C, 80.8%; RIHI: A/B, 88.9%)

The IIHI is mostly due to elevated nutrients and benthic growth. The RIHI is an A/B with the main impacts being invasive perennial alien species, which were cleared at the site, but recruiting in large numbers again.

15.5.2 Diatoms (C EC)

The assessment is based on a sample taken during 2007 and a single sample taken during the current assessment. During 2007 the biological water quality was in a D category mainly due to very high organic loading. However, the latest sample indicates that the biological water quality was moderate to good with moderate pollution levels and the EC was a B/C. Nutrient levels are elevated at times and organic pollution levels are very low. This assessment is of low confidence as it is uncertain if elevated flows in the system might have a dilution effect at this site or if there is really an improvement in water quality. Therefore the EC was set at a C.

15.5.3 Fish (C EC, 63.8%)

All of the fish species (8 out of 8) expected under reference conditions are still expected to be present under the present conditions at this site and in the river. *L. capensis* was sampled at an increased/improved FROC from reference conditions (sampled in high densities), indicating that habitat conditions are suitable for species with a preference for a variety of flow depth classes, and species which are moderately intolerant to no flow conditions (*B. aeneus*, *L. kimberleyensis*, and *L. capensis*). The FROC of ASCL and LUMB have been reduced due to their preferred habitat loss (loss of FS and deterioration of substrate (cobbles and rock) habitat due to benthic growth. The FROC of the rest of the species is expected to remain unchanged. All flow depth classes are represented. Large pools were present and all the species will be able to utilise the pools as cover and refugia. Good spawning habitat is present for spawning during high floods, and pools with cover are present as refugia and nursery area, after floods. The presence of exotic and introduced fish species will also negatively impact on the fish species present in the system (competition,

predation, habitat alteration). The FROC of *C. gariepinus* (quiet water benthic species), *P. philander* and *T. sparrmanii* is unchanged from reference as these species are moderately tolerant to tolerant to no-flow conditions. Habitat diversity is also high in terms of their different habitat preferences (Cover – water column, bedrock, rocks and cobbles, instream veg., marginal aquatic veg. and tree overhang etc.)

The main present impacts on the fish are decreased wet season base flows and the loss of flow and especially FD and FS habitat, most probably due to water abstraction upstream, and increased dry season base flows due to Orange River water being transferred to improve water quality (loss of FS). Smaller weirs and water abstraction upstream are the main reasons for flow modification. The water quality is also negatively affected due to agriculture.

15.5.4 Macroinvertebrates (C EC, 66%)

Macroinvertebrates were sampled using the standard SASS5 method. Habitat available was Stones in current (SIC), Stones out of current (SOOC), Marginal vegetation in current (MVIC), aquatic Vegetation (AV), Marginal vegetation out of current (MVOC), Gravel sand and mud (GSM). No Aquatic vegetation (AV) was present at the site. For list of families present in the sample please refer to the MIRAI.

SASS results:

Oct 2010: SASS5 score: 104 No of Taxa: 23 ASPT: 4.5

Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Pyralidae, Perlidae, Hydropsychidae >2spp, Dixidae, Chlorocyphidae, Tricorythidae, Philopotamidae, Hydraenidae, Atyidae and Elmidae. The only key taxa observed was Baetidae (>2 spp) and were abundant.

15.5.5 Riparian vegetation (B EC, 83.7%)

The assessment was done using VEGRAI level 4.

Marginal Zone:

Various vegetation components exist:

1) *G. virgatum* and *Cyperus marginatus* where riffle and cobble/boulder occur (not dominant).
2) High density *P. australis*, often with extensive algae and *Azolla* sp.
3) Extensive aquatic vegetation in pools with *Ceratophyllum* and *Potemogeton* dominant.
4) *Juncus* sp and *Schoenoplectus* sp with hydrophylic grasses along boulder bars where reeds do not occur.

Lower Zone:

Two components:

1) High density reed beds, especially RB.
2) Sedge and grasses along boulder beds as in marginal zone.

Upper Zone:

RB: Reeds beds (*P. australis*); LB: Open boulder beds with grasses and *Acacia karoo* as dominants, *Eucalyptus camuldensis* has been removed but has a high degree of recruitment.

MCB:

RB only: Open rocky cliff with terrestrial grasses and some terrestrial *Acacia* species e.g. *A. burkei.*

15.5.6 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 15.4.

Table 15.4 OSAEH 29.5: Causes and sources

	PES	Causes	Sources	F/NF
Rip veg	B	Altered species composition.	Small impact of alien vegetation (5% annuals, 5% perennial mainly *Eucalyptus camuldensis*). Elevated nutrients have resulted in higher densities of aquatic vegetation.	NF
		Increased reed.	Flow regulation and reduced flooding disturbance upstream of site, but response appears small.	F
Fish	C	Loss of mainly FD and FS habitat as a result of flow modification (especially during naturally low flow periods).	Smaller weirs and water abstraction for farming and irrigation upstream and increased dry season baseflows from Orange River transfer.	F
		Lower breeding success and recruitment for fish = lower FROC.	Lower, less and/or no natural flushes and smaller floods. Flow modification due to smaller weirs and water abstraction for farming and irrigation upstream	
		Loss of species diversity or numbers due to loss of habitat diversity due to lower flows and floods during wet seasons.	Flow modification due to smaller weirs and water abstraction for farming and irrigation upstream.	
		Loss of habitat with substrate (cobbles and rock), and water column in FD and FS due to lower than natural wet season baseflows.	Flow modification due to smaller weirs and water abstraction for farming and irrigation upstream.	
		Decreased species diversity and abundance.	Presence of exotic and introduced species.	NF
		Enrichment and impaired water quality.	Agriculture upstream.	
		Presence of weirs as migration barriers (breeding, feeding and dispersal), also causing loss of habitat of some species (inundation).	Smaller weirs in area.	
Inverts	C	Sedimentation.	Agriculture and urbanization.	F
		Poor water quality and associated benthic growth.		NF

15.6 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 15.5.

Table 15.5 OSAEH 29.5: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Rip veg	B	Negative	B/C	>5 years	The high degree of recruitment of perennial alien species will cause the PES to deteriorate over time. This trend may also be stable if these aliens are removed once they get bigger, since other aliens have been removed from site	3
Fish	C	Stable			The site was surveyed during the dry season base flow period (low flow), and certain fish species with a moderate intolerance to no flows were sampled in high numbers. It is expected that fish will use the pools for refuge areas, and all of the expected species are still expected to be present. Spawning habitat is present, and can be utilized by fish during higher flows or floods. The PES is a C, and will remain stable under current conditions (low flow – dry season base flow). Most species sampled in high densities.	3
Inverts	C	Stable			The macroinvertebrates have already reacted to the current conditions.	1

15.7 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 15.6. The Instream EC is a C (64.8%).

Table 15.6 OSAEH 29.5: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	4	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	3	90		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	4	100		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	90		
FISH ECOLOGICAL CATEGORY	14	380	**63.8**	**C**
MACROINVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	3	100		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	3	100		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	90		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**8**	290	**66**	**C**
INSTREAM ECOLOGICAL CATEGORY (Excl confidence)		670	**64.9**	**C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	3	0.60	38.28	
Confidence rating for **macroinvertebrate** information	2	0.40	26.40	
	5	1.00	64.68	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**C**	

To determine the EcoStatus, the VEGRAI EC and confidence is included in the EcoStatus assessment index (Table 15.7). The EcoStatus EC is a C.

Table 15.7 OSAEH 29.5: Instream EC

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**83.7**	**B**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	2.6	0.46	29.50
Confidence rating for riparian vegetation zone information	3.1	0.54	45.52
	5.7	1.00	75.02
ECOSTATUS	**EC**		**C**

15.8 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised in Table 15.8.

Table 15.8 OSAEH 29.5: EcoClassification results

Driver Components	PES	Trend
IHI: INSTREAM	B/C	
IHI: RIPARIAN	A/B	
DIATOMS (WQ)	C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C	Stable
INSTREAM	C	
RIPARIAN VEGETATION	B	Negative
ECOSTATUS	C	

It is evident that there is a discernable difference in the 2007/2008 and 2010 results of the Riparian vegetation assessment. The site is now part of the Mokala National Park and together with Working for Water a lot of exotic species have been removed. This is ongoing and the vegetation has improved drastically (*Pers. comm*. H Bezuidenhout).

15.9 SUITABILITY AS FUTURE MONITORING SITE

15.9.1 Biotopes present

Good quality and quantity of cobble biotope is present for macroinvertebrate sampling. A diversity of instream habitats is present. Very good habitat diversity and cover occurs for expected fish species. Pools are abundant for water column cover and refugia for fish. This site could serve as a good fish spawning area during high floods with ample marginal vegetation and substrate present (cobbles and rocky areas). All fish flow depth classes are present and well represented. Upstream water abstraction and weirs result in flow modification which impacts negatively on the available habitat. Benthic algae are present due to nutrient enrichment. Riparian obligate species are present and dominant at the site. The site is situated within a protected area. The river is not wadeable and a boat would be needed to cross the river.

Component	Advantages	Disadvantages	Conf
Rip veg	Riparian alluvial and bedrock habitats available Riparian obligate species present (rheophytes, helophytes and bank species) and dominant at the site Site within protected area	River not wadeable, would need a boat to cross Close proximity of road on LB	5
Fish	Very good habitat diversity and cover for all expected species Marginal and instream aquatic veg., overhanging veg., water column, and substrate, abundant for fish cover Pools abundant for water column cover and refugia No NPS pollution observed Could serve as good spawning area during high floods with ample marginal veg. and substrate	Up-stream water abstraction Reduced base flows Flow modification due to weirs and abstraction upstream – decrease in base flows and floods, and impact on seasonality of smaller floods Catchment scale impacts – erosion in catchment, weirs and water abstraction, upstream Benthic growth – some enrichment	4

Component	Advantages	Disadvantages	Conf
	(cobbles and rocky areas) for spawning needs of fish All flow depth classes present and well represented Perennial flow in this reach	Deeper areas and FD are non-wadeable for sampling Some siltation, rocks were slippery.	
Inverts	Good quality and quantity of cobble biotope present Diversity of velocities present Few localised impacts Diversity of instream habitats present	Limited aquatic vegetation	2

15.9.2 Site suitability

The site suitability of each site was assessed and is provided in Table 15.9. All scores are out of 5 with 5 referring to very high suitability (see below).

Very High: 4.1 – 5 High: 3.1 – 4
Moderate: 2.1 – 3 Low: 1.1 – 2
Very Low: 0 – 1

Table 15.9 OSAEH 14.9: Biophysical site suitability

Site	Rip veg	Fish	Inverts	Average	Median	Max	Min	Comments
OSAEH 29.5	3.5	4.5	3	3.67	3.5	4.5	3	**High** suitability for biotic component monitoring. There are both flow and non-flow related impacts and alien vegetation invasion is not a main impact. There are also benefits to conservation objectives since the site falls within a protected area.

16 OSAEH 26.1: DOULAS WEIR (VAAL RIVER)

16.1 SITE DESCRIPTION

Location	OSEAH 26.1	**Altitude**	997 m
Longitude	23.80646	**Latitude**	-29.00083
EcoRegion	Ghaap Plateau 30.01	**Quaternary catchment**	C92C
Water Management Area	Lower Orange	**Geomorphological zone**	Foothill

This site is situated approximately 1.6 km downstream of Douglas Weir. The substratum consists of cobbles, rock, gravel and sand. The site has good habitat diversity with all fish flow depth classes and cover well represented. Undercut banks and root wads are, however, absent. The surrounding land use consists of natural fields, pastures and agriculture. The main channel is about 500 m wide at the site with numerous side or secondary channels. Habitat types present include rapids (5%), riffles (10%), runs (15%), glides (20%), and pools (50%). Riparian vegetation includes trees, shrubs, grasses, sedges and reeds.

Figure 16.1 OSAEH 26.1: Small rapid and riffle in Vaal River below Douglas Weir, note benthic growth on rocks

16.2 BIOTIC SAMPLING

At the time of sampling, marginal vegetation was abundant and consisted of reeds and sedges. Abundant filamentous algae and benthic growth or rocks was observed. No local erosion was observed, however upstream erosion does occur. Slight sedimentation occurred and no odours were detected. The water was slightly opaque. No bed- or channel modification was present at the site. Some exotic vegetation removal was observed, with some exotic vegetation encroachment present.

16.2.1 Fish

The fish sampling was conducted at the site during October 2010. A variety of depth classes were sampled for 60 minutes. Sampling and data analysis was followed according to Kleynhans *et al*. (2008). A summary of the site conditions during sampling is provided below. Abundance of habitat was rated as:

- 0 = absent 1 = rare

- 2 = sparse 3 = moderate
- 4 = abundant 5 = very abundant

Fish velocity-depth classes and cover present at the site

SLOW DEEP	OW SHALLOW	ST DEEP	FAST SHALLOW
5	5	5	5
getation			
3	3	3	0
and root wads			
0	0	0	0
3	3	5	5
nytes			
5	5	3	2
5	5	5	5

Habitats sampled and effort

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Electro shocker (min)	15 min	15 min	15 min	15 min

16.3 DATA AVAILABILITY

Detailed information regarding available data is provided in Table 16.1.

Table 16.1 OSAEH 26.1: Summary of data availability

Comp	Data availability	Conf
IHI	Google Earth imagery. Information from Lower Vaal Reserve study.	3
Riparian vegetation	Current Google Earth imagery of the site and site context. Data collected from field assessment during October 2010. Ecological reports and specialist assessments for this study; previous Reserve determination report SANBI floristic distribution data (2009) Literature: **Kleynhans C.J, MacKenzie J., Louw M.D.** 2007a. Module F: Riparian Vegetation Response Assessment Index in River Classification: Manual for EcoStatus Determination (version 2). Joint Water Commission and Department of Water Affairs and Forestry report. WRC Report No. TT333/08. **Low B.A., Rebello A.G.** (eds) 1998. Vegetation of South Africa, Lesotho and Swaziland**.** Department of Environmental Affairs and Tourism, Pretoria. **Mucina L. & Rutherford M.C.** (eds) 2006. Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19*. South African National Biodiversity Institute, Pretoria. **Van Wyk B. & Van Wyk P**. 2009. Field Guide to trees of Southern Africa. 12th Impression. Struik Nature Publishers, Cape Town.	4
Fish	Google Earth imagery. One site visit and fish sampling during October 2010. **Kleynhans, C.J., Louw, M.D & Moolman, J**. 2007b. Module D (Volume 2): Reference Frequency of Occurrence of Fish Species in South Africa: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry Report. WRC Report No. TT330/08. Water Research Commission, Pretoria, South Africa. **Rivers Data base** (2007): *Database on fish distribution in South African Rivers*. **Scott *et al.*** (2006): *Atlas of Southern African Freshwater Fishes*.	4
Inverts	Google Earth imagery. One site visit and fish sampling during October 2010.	2

16.4 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 16.2. Additional information on fish, macroinvertebrate and riparian vegetation reference conditions are also provided.

Table 16.2 OSAEH 26.1: Reference conditions

Comp	Reference conditions	Conf
Riparian vegetation	Upper Gariep Alluvial Vegetation, which is considered vulnerable (Mucina & Rutherford, 2006). **Marginal Zone:** cobble dominated communities: 1) *G. virgatum, C. marginatus, S. corymbosus, S. brachycerus.* 2) *S. mucronata and P. australis* where alluvium deposits or consolidates. **Lower Zone:** Similar to marginal zone, with dense reed beds **Upper Zone including MCB:** Mixture of sedges, grasses and woody species.	3.5
Fish	Reference conditions as set for the NRHP site, C9VAALDOUGL, (Kleynhans *et al.,* 2007b), which is also the OSEAH 26.1 sampling site, was used as a starting point for setting reference conditions. See Table 15.3 for a list of the reference fish species.	4
Inverts	Reference conditions are based on professional judgement and Rivers Database information. The reference SASS5 score is 200 and the ASPT is 6.5.	2

16.4.1 Fish

Reference conditions broadly refer to "expectations on the state of aquatic biological communities in the absence of human disturbance and pollution". In the context of this report, it refers specifically to the fish species present in a particular river reach and their frequency of occurrence under reference habitat conditions. Reference conditions as set for the NRHP site, C9VAALDOUGL, (Kleynhans *et al.,* 2007b), which is also the OSEAH 26.1 sampling site, was used as starting point for setting reference conditions.

Professional opinion and experience; sampling; and habitat and site observations were further used to obtain a derived FROC from the reference FROC, based on the species habitat and condition preferences and tolerances (Table 16.3).

Eleven indigenous fish species are expected under reference conditions and are listed in Table 15.3. An exotic fish species *Cyprinus carpio* is also listed for this system.

Table 16.3 OSAEH 26.1: Reference fish species

Expected Reference and Habitat derived FROC of fish at OSAEH 26.1 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Austroglanis sclateri	Rock catfish	ASCL	3	1
Barbus anoplus	Chubbyhead barb	BANO	3	2
Barbus paludinosus	Straightfin barb	BPAU	3	3
Barbus trimaculatus	Threespot barb	BTRI	3	2
Labeobarbus aeneus	Smallmouth yellowfish	BAEN	3	3
Labeobarbus kimberleyensis	Largemouth yellowfish	BKIM	3	2
Clarias gariepinus	Sharptooth catfish	CGAR	3	3
Labeo capensis	Orange River labeo	LCAP	3	2
Labeo umbratus	Moggel	LUMB	3	2
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	3	3
Tilapia sparrmanii	Banded tilapia	TSPA	3	3
FROC ratings: 0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10 - 25%) 3 = present at about >25 - 50 % of sites 4 = present at most sites (>50 - 75%) 5 = present at almost all sites (>75%)				
ALIEN AND INVASIVE SPECIES				
Cyprinus carpio	Common Carp	CCAR		

16.4.2 Macroinvertebrates

Macroinvertebrate taxa expected under reference conditions include:
Hydropsychidae (>2 spp.), Baetidae (>2 spp.), Tricorythidae, Elmidae/ Dryopidae, Atyidae, Leptophlebiidae, Hydracarina, Simuliidae, Coenagrionidae, Naucoridae, Hydroptilidae, Tipulidae, Corbiculidae, Caenidae, Gerridae, Veliidae/ Mesoveliidae, Dytiscidae/ Noteridae, Gyrinidae, Ceratopogonidae, Porifera, Hydrophilidae, Turbellaria, Potamonautidae, Corixidae, Chironomidae, Oligochaeta, Tabanidae, Gomphidae, Pleidae, Ancylidae, Leptoceridae, Hydrometridae, Dixidae, Chlorocyphidae, Ecnomidae, Philopotamidae, Aeshnidae, Notonectidae, Culicidae, Muscidae, Belostomatidae, Nepidae, Lymnaeidae, Physidae, Planorbidae, and Hirudinea.

16.5 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information provided with this report.

16.5.1 Index of Habitat Integrity (IIHI: C, 76.3%; RIHI: B/C, 79.6%)

The IIHI condition is mostly due to poor bed conditions, with elevated levels of nutrients and associated benthic growth, and to a less extent loss of longitudinal connectivity due to weirs. The RIHI is a B/C with the main impacts being poorer bank conditions due to alien invasive species, especially *Eucalyptus camuldensis*. Reduced base flows and small floods also facilitate an increase in marginal and lower zone vegetation and flow regulation promoted reed expansion and density.

16.5.2 Diatoms (B/C EC)

The assessment is based on single sample taken during the current assessment. Pollution levels were low along with organically bound nitrogen levels. Nutrient levels may be problematic at this site but due to elevated flows this impact is ameliorated.

16.5.3 Fish (C EC, 68.7%)

All of the eleven species expected under reference conditions are still expected to be present under the present conditions at this site and in the river.

Note: *L. capensis* (juveniles) and *L. aeneus* (mature large) were sampled, indicating that habitat conditions are suitable for species (with different length classes life stages) with a preference for a variety of flow depth classes, and species which are moderately intolerant to no flow conditions (*L. aeneus*, *L. kimberleyensis*, and *L. capensis*).

The FROC of some species is expected to have been reduced due to deterioration of certain habitat conditions.

All flow depth classes are represented. But due to flow modification and reduced base flows there is a loss of FD and FS habitats resulting in a loss of water column and substrate as cover, reducing the FROC of *A. sclateri*, *L. capensis* and *L. kimberleyensis*.

Due to reduced flows there is also a loss in vegetation overhang as cover resulting in a loss of preferred habitat and a reduced FROC for *B. anoplus* and *B. trimaculatus*.

Increased benthic growth also reduced the habitat suitability (substrate – cobbles and rocks) for *A. sclateri*, *L. kimberleyensis*, *L. capensis*, and *L. umbratus*, further aiding in their reduced FROC.

Large pools were present and all the species will be able to utilise the pools as cover and refugia.

Good spawning habitat is present for spawning during high floods, and pools are present as refugia and nursery area, after floods.

The presence of carp, which can prey on fish eggs and causes bio-turbation, may also negatively impact on the fish species present in the system.

The FROC of *C. gariepinus* (quiet water benthic species), *P. philander* and *T. sparrmanii* is unchanged from reference as these species are moderately tolerant to tolerant to no-flow conditions. Habitat diversity is also high in terms of their different habitat preferences (SD, SS, and Cover – water column, rocks and cobbles, instream veg., and marginal aquatic veg. etc.).

The main present impact on the fish is decreased flows and the loss of flow and especially FD and FS habitats with the loss of substrate i.t.o. lower flow and benthic growth, most probably due to water abstraction and enrichment due to agricultural activities upstream.

Main impacts on the fish: Weirs, enrichment, and water abstraction upstream are the main reasons for the flow modification i.e. reduced dry season base flow, and increased benthic growth.

16.5.4 Macroinvertebrates (C/D EC, 61.4%)

Macroinvertebrates were sampled using the standard SASS5 method. Habitat available was Stones in current (SIC), Stones out of current (SOOC), Marginal vegetation in current (MVIC), Marginal vegetation out of current (MVOC), Gravel sand and mud (GSM). No Aquatic vegetation (AV) was sampled at the site. For list of families present in the sample please refer to the MIRAI.

SASS results:

Oct 2010:	SASS5 score: 128	No of Taxa: 28	ASPT: 4.6

Key taxa expected but not observed were generally those that are sensitive to water quality changes, such as Hydropsychidae (>2spp), Aeshnidae, Atyidae, Chlorocyphidae, Dixidae, Ecnomidae, Gerridae, Hydrometridae, Philopotamidae, Tricorythidae and Vellidae/ Mesovellidae.

16.5.5 Riparian vegetation (B EC, 82.9%)

The assessment was done using VEGRAI level 4. The overall score for the site is carried by the marginal and lower zones which are in much better condition than the upper zone or MCB.

Marginal Zone:

Close to reference, with a high degree of algae, slightly reduced woody component and elevated sedge cover due to a combination of grazing of grasses and flow regulation.

Lower Zone:

Similar to marginal zone with decreasing impacts from LB to RB; extreme *Salix mucronata* density on RB, high levels of recruitment of *G. virgatum* and *Eucalyptus camuldensis* (exotic species).

Upper Zone:

Two components:

1) Cobble beds dominated by *Schoenoplectus* and *Cyperus* species.

2) Alluvial bars dominated by woody species such as *A. karoo, Z. mucronata, D. lyceoides* and the alien *E. camuldensis.*

MCB:
Woody dominated community; LB with high degree of alien perennials and clearing for the canal, rail road and physical earth dumping: RB woody, high density with small impacts.

16.5.6 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 16.4.

Table 16.4 OSAEH 26.1: Causes and sources

	PES	Causes	Sources	F/NF
Rip veg	B	Reduced cover of indigenous riparian obligate species, mainly on upper zone and LB.	Physical clearing, removal, dumping and high grazing pressure.	NF
		Altered species composition.	Up to 20% cover by perennial alien species, especially *Eucalyptus camuldensis.*	
		Increased sedge and reed cover.	Flow regulation and reduced flooding disturbance facilitates an increase in reed and sedge cover and density in the marginal and lower zone, especially when accompanied by grazing and clearing.	F
Fish	C	Loss mainly FD and FS habitat as a result of flow modification (especially during naturally low flow periods).	Weirs and water abstraction for farming and irrigation upstream.	F
		Lower breeding success and recruitment for fish = lower FROC.	Lower, less and/or no natural flushes and smaller floods. Flow modification due to weirs and water abstraction for farming and irrigation upstream.	
		Loss of species diversity or numbers due to loss of habitat diversity due to lower flows.	Flow modification due to weirs and water abstraction for farming and irrigation upstream.	
		Loss of habitat with substrate (cobbles and rock), and water column in FD and FS due to lower than natural flows.	Flow modification due to weirs and water abstraction for farming and irrigation upstream.	
		Loss of vegetation overhang and habitat for cover.	Reduced flows – flow modification.	
		Decreased species diversity and abundance due to presence of carp.	Presence of alien species (carp) introduced for aquaculture and angling.	NF
		Enrichment, increased benthic growth and loss of substrate and habitat.	Agriculture upstream.	
		Presence of weirs as migration barriers (breeding, feeding and dispersal), also causing loss of habitat of some species (inundation).	Weirs in area.	
Inverts	C/D	Loss of instream habitat.	Flow modification due to weirs and abstraction for agriculture.	F
		Poor water quality and associated benthic growth.	Agriculture	NF

16.6 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 16.5.

Table 16.5 OSAEH 26.1: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Rip veg	B	Negative	B/C	> 5 years	Many *Eucalypt* seedlings present at the site, and supported by large population of mature adults will certainly increase the alien infestation over time and reduce EC	3
Fish	C	Stable			The site was surveyed during the dry season base flow period (low flow), and certain fish species with a moderate intolerance to no flows were sampled. It is expected that fish will use the pools for refuge areas, and all of the expected species are still expected to be present. Spawning habitat is present, and can be utilized by fish during higher flows or floods. The PES is a C, and will remain stable under current conditions (low flow –	3

	PES	Trend	Trend PES	Time	Reasons	Conf
					dry season base flow).	
Inverts	C/D	Stable			The macroinvertebrates have already reacted to the current conditions.	1

16.7 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 16.6. The Instream EC is a C (65.8%).

Table 16.6 OSAEH 26.1: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	4	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	4	100		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	4	100		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	3	90		
FISH ECOLOGICAL CATEGORY	15	390	**68.7**	**C**
MACROINVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	3	100		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	2	90		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	90		
MACROINVERTEBRATE ECOLOGICAL CATEGORY	**7**	280	**61.4**	**C/D**
INSTREAM ECOLOGICAL CATEGORY (Excl confidence)		670	**65.4**	**C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	3	0.60	41.22	
Confidence rating for **macroinvertebrate** information	2	0.40	24.56	
	5	1.00	65.78	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**C**	

To determine the EcoStatus, the VEGRAI EC and confidence is included in the EcoStatus assessment index (Table 16.7). The EcoStatus EC is a C.

Table 16.7 OSAEH 26.1: Instream EC

RIPARIAN VEGETATION	EC %	EC	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**82.9**	**B**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**

Confidence rating for instream biological information	2.6	0.47	31.10
Confidence rating for riparian vegetation zone information	2.9	0.53	43.71
	5.5	1.00	74.81
ECOSTATUS	**EC**		**C**

16.8 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised in Table 16.8.

Table 16.8 OSAEH 26.1: EcoClassification results

Driver Components	PES	Trend
IHI: INSTREAM	C	
IHI: RIPARIAN	B/C	
DIATOMS (WQ)	B/C	
Response Components	**PES**	**Trend**
FISH	C	Stable
MACRO INVERTEBRATES	C/D	Stable
INSTREAM	C	
RIPARIAN VEGETATION	B	Negative
ECOSTATUS	C	

16.9 SUITABILITY AS FUTURE MONITORING SITE

16.9.1 Biotopes present

A good quantity of cobble biotope is present for SASS sampling. A diversity of velocities is present, however extensive filamentous algae and benthic growth decreases the quality of the cobble biotope. Limited overhanging vegetation out of current is present for use by macroinvertebrates. A very good habitat diversity and cover is present for all expected fish species. Marginal and instream aquatic vegetation, overhanging vegetation, water column and substrate are all abundant for fish cover. Pools are abundant and function as water column cover and refugia for fish. Perennial flow is present in this reach of the river. Riparian alluvial and bedrock habitats are available. Riparian vegetation obligate species are present and dominant at the site. A disadvantage for this site is its close proximity to an upstream weir and transfer scheme.

Component	Advantages	Disadvantages	Conf
Rip veg	Riparian alluvial and bedrock habitats available, with pools Riparian obligate species present (rheophytes, helophytes and bank species) and dominant at the site	Close proximity to upsteam weir and transfer scheme	5
Fish	Very good habitat diversity and cover for all expected species	Up-stream water abstraction and in river reach	4

Component	Advantages	Disadvantages	Conf
	Marginal and instream aquatic veg., overhanging veg., water column, and substrate, abundant for fish cover Pools abundant for water column cover and refugia No non-point source pollution observed Good spawning area during high floods with ample marginal veg. and substrate (cobbles and rocky areas) for spawning needs of fish All flow depth classes present and well represented Perennial flow in this reach	Reduced base flows Flow modification due to weirs and abstraction upstream – decrease in base flows and floods, and impact on seasonality of smaller floods Catchment scale impacts – erosion in catchment, weirs and water abstraction. Heavy benthic growth –enrichment Some siltation with the algae growth render rocks slippery Douglas Weir upstream Water transfer in area from Orange River	
Inverts	Good quantity of cobble biotope present Diversity of velocities present	Limited overhanging vegetation out of current available for use by macroinvertebrates Algae covering cobbles	2

16.9.2 Site suitability

The site suitability of each site was assessed and is provided in Table 16.9. All scores are out of 5 with 5 referring to very high suitability (see below).

Very High: 4.1 – 5 High: 3.1 – 4
Moderate: 2.1 – 3 Low: 1.1 – 2
Very Low: 0 – 1

Table 16.9 OSAEH 26.1: Biophysical site suitability

Site	Rip veg	Fish	Inverts	Average	Median	Max	Min	Comments
OSAEH 29.5	3	4	2.5	3.17	3	4	2.5	**High** suitability for biotic component monitoring, but a difficult site to assess for riparian vegetation as it is an anastomosing site with channel width over 400 m. Flow is also regulated and manipulated.

17 OSAEH 26.17: GIFKLOOF (ORANGE RIVER)

17.1 SITE DESCRIPTION

Location	Gifkloof	**Altitude**	804 m
	Situated downstream of Gifkloof gauging weir (D7H005Q1).		
Longitude	21° 24.046	**Latitude**	28° 26.240
EcoRegion	Nama Karoo 26.05	**Quaternary catchment**	D73E
Water Management Area	Lower Orange River	**Geomorphological zone**	Lowland River
Management Resource Unit	D	**Natural Resource Unit**	D

The Gifkloof site (OSAEH is situated in the middle parts of the Lower Orange River (usually described as the section of river downstream of the Vaal-Orange River confluence and upstream of the Augrabies Falls) that falls within the large Nama Karoo EcoRegion (26.05). The geomorphic features of the river channel in this section correspond to a “Lowland river”.

The site is situated approximately 0.4 km downstream of Gifkloof Weir (Figure 17.1). Various habitat types were available at the site namely stones in current (rapids and riffles, see Figure 16.2), marginal vegetation (Figure 16.3) and a limited area of gravel and sand. The macro-channel width was >50 - 100 m and the active channel and surface water width was 20 – 50 m. The substratum in the river was mostly bedrock, boulders, cobbles and pebbles with limited sand and gravel. A DWA technician at the Gifkloof weir indicated during the site visit that the water level was lower than normal for the time of the year. The river bank (just above the waterline) was covered with cobbles, boulders and pebbles and as a result of this very little gravel/sand/mud was found along the banks. Flow at the site varied from low (0.06 m/s) to very high (1.14 m/s) in the rapid riffle section and low (0.03 m/s) to moderate (0.35 m/s) in the marginal vegetation.

Figure 17.1 Gifkloof gauging weir (D7H005Q1) situated upstream of site

Figure 17.2 Rapids and Riffles at Gifkloof

Figure 17.3 Marginal vegetation at Gifkloof

17.2 BIOTIC SAMPLING

17.2.1 Fish

The fish sampling was conducted at the site (OSAEH 26.17) approximately 0.4 km downstream of the Gifkloof Weir. A river stretch of approximately a 100 m long, representing a pool, rapid, run, pool sequence, was sampled for fish along the middle and left bank of the river. Five sampling points were surveyed in this stretch of river that was flowing quite strongly at the time of sampling.

A description of each sampling point is presented in Table 17.1, while an assessment of the fish cover available at each sampling point is presented in Table 17.2. An additional point was sampled approximately 14 km downstream at the Upington Waterworks (28°27.146S; 21°15.613E) where the educational presentations and Mini-Sass demonstration took place. Although the purpose of that sampling was to provide information and to demonstrate the fishing techniques used, the results were also considered in the calculation of the FROC and the FRAI.

Table 17.1 Description of the various sampling points surveyed at Gifkloof. (SD, Slow deep; SS, Slow shallow; FD, Fast deep; FS, Fast shallow; Habitat types based on the definition of Kleynhans, 1999)

Sampling point	Description	Sampling method and effort*
1	A run (fast glide) representing predominantly FD habitat over a substrate of bedrock and rubble downstream of the rapid. Water depths measured varied between 43 cm and 76 cm (mean depth 56 cm). Velocities of between 0.242 m/s and 0.586 m/s (mean velocity 0.40 m/s) were recorded in the run. Fish cover comprised mainly of substrate cover.	Electroshocking (wading) 7 min
2	Predominantly shallow pool area (SS) along the left bank of the river downstream of the rapid area. The substrate comprised mainly bedrock and rubble with the substrate providing the most fish cover. Depths of between 24 cm and 69 cm (mean depth 36.63 cm). Velocities of between 0 and 0.327 m/s (mean velocity 0.06 m/s) were measured. .	Electroshocking (wading) 12 min
3	A rapid approximately 6 m long. FD and FS habitat over mainly bedrock. Depths of between 14 cm and 34 cm were measured (mean depth 32.5 cm). Surface flow varied between 0.271 m/s and 0.832 m/s (mean velocity 0.550 m/s). Fish cover provided mainly by the substrate.	Electroshocking (wading) 5 min*
4	A pool, comprising of predominantly SD habitat over a substrate of boulders and cobbles. The pool is situated immediately upstream of the rapid and is fringed with reeds along the left bank. Depths ranged between 21 cm and 91 cm (mean depth 61 cm). No flow was detected with the flow meter. Fish cover mainly provided by the substrate and the reeds.	Electroshocking (wading) 10 min
5	Predominantly FD and FS habitat over a substrate of bedrock and rubble upstream of the rapid. Water depths of between 24 cm and 46 cm (mean depth 33 cm) were measured. Velocities varied between 0.145 m/s and 0.683 m/s (mean velocity 0.550 m/s). Fish cover comprised mainly of substrate cover.	Electroshocking (wading) 7 min
6	FS, SD and SS habitat over bedrock, boulders and cobbles. Substrate cover predominant.	Electroshocking (wading) Approximately 10 min

*Sampling effort at the site was limited at the site due to PR obligations.

Table 17.2 Fish habitat assessment (0, absent; 1, rare; 2, sparse; 3, common; 4, abundant; 5, very abundant; based on the description of Kleynhans 1999)

Velocity-depth class	SLOW DEEP					SLOW SHALLOW					FAST DEEP					FAST SHALLOW				
Sampling points	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
ABUNDANCE	1	2	0	4	3	0	3	1	3	2	5	0	3	0	4	2	2	4	0	2
Overhanging vegetation	0	0	0	2	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0
Undercut banks and root wads	0	0	0	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Substrate	4	4	0	3	4	0	4	3	3	4	4	0	4	0	4	4	4	4	0	4
Aquatic vegetation	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Water Column	3	3	0	4	4	0	1	0	1	1	3	0	3	0	3	1	1	1	0	1

17.2.2 Riparian vegetation

A higher emphasis was placed on the suitability of the site for macroinvertebrates and fish habitats. A suitable sample plot for the riparian vegetation was placed as close as possible to the habitats that were selected by the macroinvertebrate- and fish specialists. The size of the plot was

determined by the surface area that would include the most diagnostic and dominant species present for that part of the Lower Orange River.

Delineation of the riparian zone:
The lateral borders of the site were determined by the surface area in which no more new species could be identified. The longitudinal borders included the marginal, lower and upper zones.

Samples were taken on the western bank of the river. The sample plot measured 96 m x12 m.

17.3 DATA AVAILABILITY

The fish data from two fish surveys done in the past six months at sites in Natural Resource Unit (NRU) D (see WFA, 2010a) were used to calculate the Present Ecological State (PES) of the fish community (see Table 17.3). These surveys were mainly done at two sites, namely Boegoeberg (Kotze and Koekemoer, 2010) and Gifkloof (this study). Both these sites are situated in the 26.05 Level II EcoRegions and the Lowland river geomorphic zone.

Two constraints with regards to fish sampling should be noted. First, sampling time at the site was limited due to the team's involvement with the educational programme scheduled for the afternoon. Second, a number of fish was missed during electro-shocking in the fast-flowing deeper habitats (FD) due to the strong flow present at the time of sampling.

The Macroinvertebrate data from samples mentioned in Table 16.3 were used to determine the Present Ecological State (PES) category for the OSAEH 26 17. Dallas (2007) SASS interpretation guidelines as well as the MIRAI method were used.

Detailed information regarding available data is provided in Table 17.3.

Table 17.3 OSAEH 26.17: Summary of data availability

Comp[1]	Data availability	Conf[2]
Index of Habitat Integrity (IHI)	Google Earth imagery. **Orange Senqu River Commission** (ORASECOM). 2008. Preliminary Transboundary Diagnostic Analysis. Main Report. ORASECOM. **WFA**. 2010a. Assessment of Environmental Flow Requirements. Work package 5. Deliverable 10: Resource Unit Delineation. Rivers4Africa. Pretoria. **Louw, D.** 2010. IHI results from Intermediate Reserve on Orange River. **Department of Water Affairs and Forestry (DWAF), South Africa**. 2004. Internal Strategic Perspective: Lower Orange Water Management Area. Prepared by PDNA, WRP Consulting Engineers (Pty) Ltd, WMB and Kwezi-V3 on behalf of the Directorate: National Water Resource Planning. DWAF Report No P WMA 14/000/00/0304.	3
Riparian vegetation	Google Earth imagery from 13 June 2003. (Google 2010). Data collected from field assessment in November 2010. Literature: **Bezuidenhout H. & Jardine C.L**. 2001. A reconnaissance botanical survey of the Lower Orange River (Blouputs to Onseepkans) in the Northern Cape, South Africa. *Koedoe* 44(1): 1-8. Pretoria. **Bromilow C**. 2001. Problem Plants of South Africa. Briza Publications, Pretoria. **Kleynhans C.J, MacKenzie J., Louw M.D.** 2007a. Module F: Riparian Vegetation Response Assessment Index in River Classification: Manual for EcoStatus Determination (version 2). Joint Water Commission and Department of Water Affairs and Forestry report. WRC Report No. TT333/08. **Le Roux A**. 2005. Namaqualand. South African Wild Flower Guide 1**.** Third Revision. National Botanical Society of South Africa, Cape Town. **Low B.A., Rebello A.G.** (eds) 1998. Vegetation of South Africa, Lesotho and Swaziland**.** Department of Environmental Affairs and Tourism, Pretoria. **Mucina L. & Rutherford M.C**. (eds) 2005. VEGMAP. Wall Map South African National Biodiversity Institute, Pretoria. **Mucina L. & Rutherford M.C.** (eds) 2006. Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19*. South African National Biodiversity Institute, Pretoria. **Van Wyk B. & Van Wyk P**. 2009. Field Guide to trees of Southern Africa. 12th Impression. Struik Nature Publishers, Cape Town.	4.5

Fish	Site visit and fish survey conducted at Gifkloof in November 2010. Additional sampling done at Upington Waterworks also considered. A fish survey at Boegoeberg (EFR2) conducted in in May/June 2010 by P. Kotze and J. Koekemoer (see Kotze & Koekemer, 2010).	3.5
Inverts[3]	Once off survey at Gifkloof site (NRU D and MRU D) to determine PES on 2 November 2010. Data collected by Schoolchildren using Mini-SASS on 2 November 2010 approximately 14km downstream of study site but in the same MRU D identified by WFA (2010a). Data from **Palmer (*pers communication*)** at Boegoeberg site in 2010 (In same MRU D, Lowland River and in EcoRegion 26.05). **Belcher, T. & Herdien,** E. 2009. Freshwater Assessment for the Proposed Improvement of structures along the R27, Section 10 and 11 between Kenhardt and Keimoes. CCA Environmental. Caledon Square.	3

1 Component 2 Confidence 3 Macroinvertebrates

17.4 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 17.4. Additional information on fish, macroinvertebrate and riparian vegetation reference conditions are also provided.

Table 17.4 OSAEH 26.17: Reference conditions

Comp	Reference conditions	Conf
IHI	The Reference Habitat Integrity at the site was determined using: Google Earth imagery. **Cornell, F.C. 1921**. The Lower Reaches of the Orange River. *The Geographical Journal* 57(4): 241-252. **DWA. 2009**. Development of an Integrated Water Quality management Strategy for the Upper and Lower Orange Water Management Areas. Report No 2.2 (P RSA D000/00/7909/3). Department of Water Affairs, Pretoria. **ORASECOM. 2007**. Orange River Integrated Water Resources Management Plan. Set of 12 reports. Orange Senqu River Commission. **Heath, R. & Brown, C**. 2007. Orange River Integrated Water Resources Management Plan. Environmental Considerations Pertaining to the Orange River. Orasecom Report No 005/2007. Orange Senqu River Commission. **DWA, 2004**. National water Resource Strategy. Appendix D: Lower Orange River. Department of Water Affairs, Pretoria. **DWAF, 1998a**. Orange River Development Project. Replanning Study. Hydrology and System Analysis – Orange River Basin. Department of Water Affairs & Forestry. Pretoria. **DWAF, 1998b**. Orange River Development Project – Replanning Study. Water Quality Aspects. Orange River Basin: Volume 1: Expected Water Quality Changes. Department of Water Affairs & Forestry. Pretoria. **DWAF, 1999**. Orange River Development Project Replanning Study. Main Report. Department of Water Affairs & Forestry. Pretoria. **Benade, B**. 1993. Studies on the fish populations in the regulated Orange River system within the borders of the Cape Province Volume 1: Text. Unpublished MSc degree, Department of Zoology and Entomology, University of the Free State..	2.5
Riparian vegetation	**Marginal zone:** It was expected that the vegetation communities in the marginal zone would have a combination of sedges, reeds and trees and to a lesser extent, herbaceous species. The dominant and most diagnostic species would occur in patches in a lateral fashion along the banks of the river. **Lower zone:** Trees would be expected to be the dominant component, with *Salix mucronata, Searsia pyroides, Acacia karoo, Ziziphus mucronata* as the dominant species. *Phragmites australis* and various sedges are also expected. The most dominant grasses that would most likely occur are *Paspalum* (under the trees in the marginal and lower zones) and *Stipagrostis* species. **Upper zone:** The Upper Zone normally host tree-dominated vegetation communities. In this case more *Acacia* species was expected. Some terrestrial grasses and herbaceous plants were also expected. Since the moisture content of the Upper Zone is less than that of the lower zone, the herbaceous layer would also be more vulnerable in these arid areas. The species composition would depend on when the sampling was done in relation to the rainy season.	

Comp	Reference conditions	Conf
Fish	**Kleynhans, C.J., Louw, M.D & Moolman, J**. 2007b. Module D (Volume 2): Reference Frequency of Occurrence of Fish Species in South Africa: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry Report. WRC Report No. TT330/08. Water Research Commission, Pretoria, South Africa. **South African Institute of Aquatic Biodiversity** (SAIAB) data base (2006). **Benade, C.** 1993. Studies on fish populations in the regulated Orange River system within the borders of the Cape Province. Unpublished M.Sc. dissertation, University of the Free State, Bloemfontein: 185 pp. **Cambray, J.A**. 1984. Fish populations in the middle and lower Orange River, with special reference to the effects of stream regulation. *J. Limnol. Soc. Sth. Afr.* 10(2): 37-49. **Cambray, J.A.** 1985. Observations on spawning of *Labeo capensis* and *Clarias gariepinus* in the regulated lower Orange River, South Africa. *South African Journal of Science* 81: 318-321. **de Moor I.J. & Bruton M.N.** 1996. Alien and translocated aquatic animals in southern Africa. *Ann*. *Cape Prov. Mus. (Nat. Hist.)* 19(6). **Gaigher, I.G., Hamman, K.C.D. and Thorne, S.C**. 1980. The distribution, conservation status and factors affecting the survival of indigenous freshwater fishes in the Cape Province. *Koedoe* 23: 57-88. **Jubb, R.A.** 1972. The Hendrik Verwoerd Dam and Orange River fishes. *Piscator* 84: 22-26. **Jubb, R.A. & Farquharsan, F.L**. 1965. The freshwater fishes of the Orange River drainage basin. *South African Journal of Science* 61: 118-145. **Skelton, P.H. and Cambray, J.A**. 1981. The freshwater fishes of the middle and lower Orange River. *Koedoe* 24: 51-66. **Skelton, P.H.** 1986. Fish of the Orange-Vaal system. In: Davies, B.R. and Walker, K.F. (eds). The ecology of river systems. Dr W. Junk Publishers, Dordrecht: 143-161. **Skelton, P.H.** 2001. A complete guide to the freshwater fishes of southern Africa. Southern Book Publishers, Halfway House. See Table 2.5 for a list of the reference fish species.	4
Macroinvertebrates	Reference conditions are based on professional judgment and **Palmer, R.W.** 1996. Invertebrates of the Orange River with emphasis on conservation and management. *South African Journal of Aquatic Science* 22(1/2): 3-51. **Palmer, R.W.** 1997. Changes in the abundance of invertebrates in the stones-in-current biotope in the middle Orange River over five years. Water Research Commission Report No KV130/00. **Agnew, A.D**. 1965. A note on the fauna of the Lower Orange River. The South African Journal of Science. 61(3): 126-128. **Curtis, B, Roberts, K.S., Griffin, M., Bethune, S., Hay, C.J. & Kolberg, H**. 1998. Species richness and conservation of Namibian freshwater macro-invertebrates, fish and amphibians. *Biodiversity and Conservation* 7: 447-466. **Curtis, B.A**. 1991. Freshwater macro-invertebrates of Namibia. *Madoqua* 17(2): 163-187. **De Moor, F.C. & Car,** M. 1986. A field evaluation of *Bacillus thuringensis* var. *israelensis* as a biological control agent for *Simulium chutteri* (Diptera: Nematocera) in the middle Orange River. *Journal of Veterinary Research* 53: 43-50 (Data available on Biobase database) **Biobase** database as well as **River Health** database available at http://www.riv.co.za/Rivers/Application/Login.aspx?ReturnUrl=%2fRivers%2fApplication%2fDefault.aspx was also consulted. **Dallas, H.F.** 2007. River Health Programme. South African Scoring System (SASS) data interpretation guidelines. Prepared for the Institute of Natural Resources and Department of Water Affairs and Forestry. The reference South African Scoring System version 5 (SASS5) score for the Nama Karoo Lower ecoregion is 118 and the Average Score Per Taxon (ASPT) is 6 (Dallas, 2007). It must be noted however that only a few samples were used to determine the reference in the Lower Nama Karoo as very little data (mostly post Gariep and Vanderkloof Dams) is available in this EcoRegion. A reference set in the Macroinvertebrate Frequency of Occurrence database (not final and available from Christa Thirion at the DWA: Resource Quality Services (RQS)) as part of the MIRAI method is: SASS5: 200 and ASPT: 6.5 for the site at Gifkloof. A list of the families expected are presented in Table 16.6	3.5

17.4.1 Fish

Reference conditions broadly refer to “expectations on the state of aquatic biological communities in the absence of human disturbance and pollution”. In the context of this report, it refers specifically to the fish species present in a particular river reach and their FROC under reference habitat conditions (Kleynhans *et al.,* 2007b). The reference conditions set here should be valid for NRU D that includes the stretch of river downstream of Boegoeberg Dam to upstream of Augrabies Falls.

The reference conditions set for the FROC-site, D7ORAN-GIFKL (Kleynhans *et al*., 2007b), was used as a starting point for setting reference conditions for the present site. Various literature resources describing previous surveys and research were consulted (see Table 2.4 for a complete list) during the process. However, only results from study sites situated in the same NRU, Level II EcoRegion and geomorphic zone as D7ORAN-GIFKL were considered.

Eleven fish species are listed in the reference list for D7ORAN-GIFKL in Kleynhans *et al*. (2007b), namely *Labeobarbus kimberleyensis*, *L. aeneus*, *Barbus anoplus*, *B. paludinosus*, *B. trimaculatus*, *Labeo capensis*, *L. umbratus*, *Austroglanis sclateri*, *Clarias gariepinus*, *Pseudocrenilabrus philander* and *Tilapia sparrmanii*. These species are, however, indicated as "code 3" species. This implies that the fish species have not actually been collected and recorded at the specific site, but that they were expected to occur at the site based on historical information and data available for the reach. A number of comments are given below to serve as background for the reference FROCs listed in Table 16.5:

- Uncertainty existed about the presence of three species on the reference list: *A. sclateri*, *B. anoplus* and *L. umbratus*. According to Skelton (1986) all three these species occur in the middle Orange River. Skelton (1986) defined the Middle Orange River as stretching from downstream of the Vaal-Orange confluence to upstream of Augrabies Falls). He did, however, indicated *B. anoplus* and *L. umbratus* to be "rare" in these parts. No SAIAB (2006) records for these three species could be found for sites in the vicinity to Gifkloof. *B. anoplus* has, however, been recorded by Cambray (1984) below Boegoeberg Dam and Kanoneiland, albeit in very low numbers. Benade (1993) has also sampled a few specimens at Kanoneiland in the late 1980s. The species is known to be very abundant in Vanderkloof Dam and some of the Orange Rivers southern tributaries (Cambray, 1985; Skelton and Cambray, 1981) but become very scarce below Vanderkloof Dam (Skelton and Cambray, 1981; Cambray, 1984). Unfortunately, no information could be found on surveys done before the completion of Vanderkloof Dam, and it is uncertain whether the species was also scarce under natural conditions. It is possible that the daily fluctuations in flow downstream of the dam do not suit this limnophilic species. It was decided, based on the fact that actual records for the species' presence in the reach exist, to include the species in the reference list, but with a FROC rating of "1".

  No records for the presence of *Labeo umbratus* in the lowland geomorphic zone of the middle Orange River could, however, be found (e.g. see Skelton and Cambray, 1981; Cambray, 1984; Benade, 1993, SAIAB, 2006). A single *L. umbratus* specimen was recorded by Skelton and Cambray (1981) at Augrabies (upstream of the falls) which technically means that the species has been recorded in the middle Orange River. The species does occur at Ais-Ais and Hardap Dam in the Fish River (Skelton and Cambray, 1981; Van Zyl et al., 1995) but could not have been the source of this specimen as the species would not have able to negotiate the falls. Again, it is difficult to decide whether to include the species in the absence of data describing the natural conditions. It was decided to include the species, but with a FROC rating of "1".

  A. sclateri has not been recorded during the extensive surveys of Skelton and Cambray (1981) and Cambray (1984). The species was however recorded in the middle Orange River by Benade (1993). According to Benade (1993) *A. sclateri* has a "patchy" distribution downstream of Vanderkloof Dam, where it still occurs. He suggests the possibility that river regulation, together with the increased turbidity as a result thereof, could contribute this fragmented pattern of distribution. On the basis of Benade's (1993) records, the species was not removed from the reference list.

- It was also uncertain if the longfin eel *Anguilla mossambicus* should be considered for the reference list. Although Skelton's (2001) guide does not indicate the species to be present in the Orange River system, both Jubb and Farquharsen (1965) and Jubb (1972) mention the species being recorded in the Orange and Vaal Rivers by anglers. It is, however, not clear how the species reached these rivers (Jubb, 1972) and it was accordingly not included on the reference list.

Eleven indigenous fish species are therefore expected to have occurred under reference conditions and are listed in Table 17.5.

Table 17.5 OSAEH 26.17: Reference fish species

Expected Reference and Habitat derived FROC of fish at OSAEH 26.17 (Values used in Fish Response Assessment Index (FRAI)). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Labeobarbus kimberleyensis	Largemouth yellowfish	BKIM	2	0
Labeobarbus aeneus	Smallmouth yellowfish	BAEN	5	4
Barbus anoplus	Chubbyhead barb	BANO	1	0
Barbus paludinosus	Straightfin barb	BPAU	3	2
Barbus trimaculatus	Threespot barb	BTRI	5	5
Labeo capensis	Orange River labeo	LCAP	5	5
Labeo umbratus	Moggel	LUM	1	0
Austroglanis sclateri	Rock catfish	ASCL	1	0
Clarias gariepinus	Sharptooth catfish	CGAR	3	3
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	5	2
Tilapia sparrmanii	Banded tilapia	TSPA	4	3

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

17.4.2 Macroinvertebrates

The reference list of macroinvertebrates for the site at Gifkloof was obtained from Christa Thirion at RQS, Department of Water Affairs in Pretoria. The Macroinvertebrate FROC reference list has not been finalised as yet but a draft copy is available. Expert opinion as well as other historical data (indicated in Table 17.4) was used to set up final reference list.

The macroinvertebrate families expected at the site are indicated in Table 17.6 in the reference abundance and FROC columns. The reference abundance was determined by using all available sampling information from sites situated in the same EcoRegion and geomorphological zone as the site to be sampled. In the case of Gifkloof information from Palmer (1992) and de Moor (1986) samples at Gifkloof were used as well as historical data and articles indicated in Table 17.4. Unfortunately very little information (only Agnew, 1965) is available for the period before Gariep and Vanderkloof dams (prior to 1970) were built and therefore this reference list could be flawed.

Table 17.6 Reference abundance and FROC as well as present abundance (sample taken 2 November 2010) at OSAEH 26.17

Taxon	Ref abundance	FROC	Pres Abun 1	Pres Abun 2	Pres Abun 3	Pres freq 1
Aeshnidae	**A**	**4**		A		1
Ancylidae	**B**	**5**	B	A		3
Atyidae	**A**	**5**	B	A	A	5
Baetidae >2spp	**B**	**5**	B	B	B	5
Belostomatidae	**A**	**4**				
Bulininae	**A**	**2**				
Caenidae	**B**	**5**	B	B	A	5
Ceratopogonidae	**A**	**4**				

Taxon	Ref abundance	FROC	Pres Abun 1	Pres Abun 2	Pres Abun 3	Pres freq 1
Chironomidae	B	5	A	A	A	5
Chlorocyphidae	A	4			1	1
Coenagrionidae	B	5		A	B	3
Corbiculidae	A	5	A	A		3
Corduliidae	A	3				
Corixidae	A	4				
Culicidae	A	1	A			1
Dytiscidae/Noteridae	A	4	A	A		3
Ecnomidae	A	3		1		1
Elmidae	A	4		A	1	3
Gerridae	A	4				
Gomphidae	A	5		A	B	3
Gyrinidae	A	4	A	B	B	5
Haliplidae	A	1				
Heptageniidae	B	5	B	A		3
Hirudinea	A	4	A			1
Hydracarina	A	2				
Hydrometridae	A	1				
Hydrophilidae	A	4				
Hydropsychidae >2spp	B	5	B	B	B	5
Hydroptilidae	A	4			1	1
Leptoceridae	A	4		A		1
Leptophlebiidae	B	5	B	B	A	5
Libellulidae	A	4				
Lymnaeidae	A	3				
Muscidae	A	2			1	1
Naucoridae	A	4	A	A	1	5
Nepidae	A	2				
Notonectidae	A	3			1	1
Oligochaeta	A	4	A	B	1	5
Perlidae	A	4		A		1
Physidae	A	1			1	1
Planorbinae	A	3				
Pleidae	A	2				
Porifera	A	5	A		1	3
Potamonautidae	A	5	A	A		3
Prosopistomatidae	A	2				
Protoneuridae	A	1				
Psychodidae	A	1				
Simuliidae	B	5	B	B	C	5
Sphaeridae	A	3				
Tabanidae	A	2				
Tipulidae	A	2				
Tricorythidae	B	5	B	B	B	5
Turbellaria	A	5		A		1
Unionidae	A	1				
Veliidae/Mesoveliidae	A	4	A	A		3

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

*Red letters indicate families which have not been sampled at site before but which could be expected due to flow and habitat available at site.

Present Abundance 1: Data from November 2010 sample at Gifkloof site.
Present abundance 2: Data collected by schoolchildren at site approximately 14 km downstream of Gifkloof site.
Present abundance 3: Data from Palmer, pers. comm. (2010) sampling at Boegoeberg approximately 110 km upstream of site but still in same EcoRegion, geomorphological zone and Natural Resource Unit (NRU D) and Management Resource Unit (MRU D) from WFA (2010a).

17.4.3 Riparian Vegetation

The Gifkloof site is situated in the Nama Karoo Biome and the vegetation was firstly described by Acocks as Orange River Broken Veld in Low and Robello (1998). Hoffman (1988) changed the description to Orange River Nama Karoo and describes the riparian vegetation as abundant thickets and he listed the following species as common along the Orange River: *Tamarix usneoides* (Wild Tamarix), *Ziziphus mucronata* (Buffalo Thorn) *and Acacia erioloba* (Camel Thorn). He also mentions that *Prosopis grandulosa* (Mesquite or "Suidwesdoring") and *Rhigozum trichotomum* (Threethorn) are aggressive invaders.

This area now falls within the Succulent Karoo Biome, as described by Mucina and Rutherford (2006). The vegetation on the banks of the Orange River is classified as: AZa 3 Lower Gariep Alluvial Vegetation. The following plants were listed as important taxa and were also found on the site:

Trees: *Acacia karoo, Salix mucronata var. mucronata, Ziziphus mucronata, Prosopis glandulosa var. glandulosa, Tamarix usneoides*

Reed beds: *Phragmites australis*

Grasses and herblands: *Cynodon dactylon and Stipagrostis* species

Bezuidenhout and Jardine (2001) also encountered *Acacia erioloba, Searsia pendulina, Diospyros lyciodes,* of which *Searsia pendulina* and *Diospyros lyciodes* also occurred on the Gifkloof site. Neither of the latter two species is listed as dominant species in the AZa 3 Lower Gariep Alluvial vegetation. They are, however listed as important taxa in the AZa 4 Upper Gariep Alluvial Vegetation Type, as described by Mucina and Rutherford (2006).

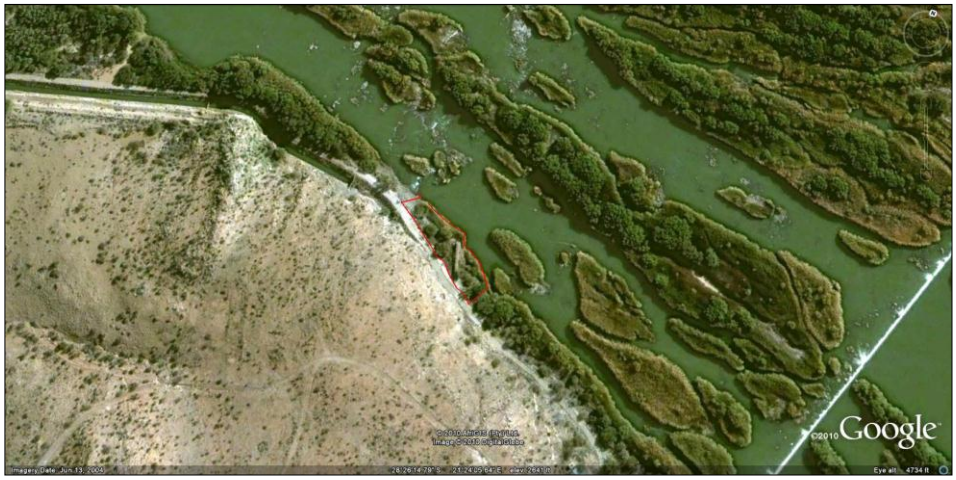

Figure 17.4 Google image of the OSAEH 26.17 (Google 2010)

This Google Image was taken on 13 June 2004 (Google 2010). The current site is indicated by a red line. It is clear from this picture that the tree cover has increased tremendously over the last 6 years (Figure 17.4).

17.5 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information provided with this report.

17.5.1 Index of Habitat Integrity (IIHI: C EC, 72.7%; RIHI: C/D EC, 63%)

The IIHI is a C (72.7%). This is mostly due to changes in hydrology due to large dams (Gariep and Vanderkloof) in Upper Orange River as well as various weirs upstream, modification of the riverbank and deteriorating water quality due to irrigation return flow to the river. The RIHI is a C/D (58.5%) with the main impact being heavy infestation of alien vegetation (Mesquite or Suidwesdoring – *Prosopis*) and a change in hydrology leading to associated changes in riparian vegetation.

17.5.2 Diatoms (B/C EC)

Diatom results are based on samples taken during 2005, 2008 – 2010 at various sites situated in the reach from Boegoeberg Dam to Augrabies. The biological water quality fluctuated between a B and C EC during 2005, 2008 – 2009, and 2010. It is evident that there is a gradual deterioration within the reach from Boegoeberg Dam to Augrabies. Nutrient levels are elevated throughout the reach and agriculture seems to be the major impact in this reach. Chloride concentrations were problematic during July 2005 in this reach. Although elevated at times, organic pollution does not seem to be a major problem in this reach. Nutrients were elevated for all sampling years indicating continuous impact, while salinity may be problematic at times. The Ecological Category (EC) for this reach which is delineated as Management Resource Unit D is a B/C.

17.5.3 Fish (B/C EC, 79.5%)

The majority of the expected fish species are still present within NRU D and MRU D although the FROC of some species have been reduced from reference conditions.

Of the two IUCN Red Data listed endemic species expected to occur in the middle Orange River, *L. kimberleyensis* ("near threathened") and *A. sclateri* ("least concern"), only the latter species has been recorded. Although the species has been described as "widely distributed" in the Orange River system (Jubb, 1967), results from previous surveys in the middle Orange River showed that relatively few specimens have been sampled (see Skelton and Cambray, 1984; Cambray, 1984; Benade, 1993; SAIAB, 2006). *L. kimberleyensis* is a visual predator associated with clear, fast-flowing waters over a sandy to gravel substrate (Mulder, 1973). The species, which is considered to be more abundant in the lower Vaal River than in the Orange River (Benade, 1993), only matures at six and eight years respectively for males and females, a factor that may contribute to its low abundance (Mulder, 1973). Benade (1993), however, expressed concern that the species gonad development, reproduction and recruitment have been adversely affected by river regulation and catchment developments.

Of the three species about which uncertainty existed whether to include them in the reference list, only one was found. One *A. sclateri* specimen was recorded at Boegoeberg by Kotze and Koekemoer (2010). The other two, *L. umbratus* and *B. anoplus*, were not recorded in the middle Orange River.

A decrease in the FROC of three species strongly associated with overhanging vegetation, namely *B. paludinosus*, *P. philander* and *T. sparrmanii* was also observed. It is not clear why this is, but the strong flow and the low abundance of overhanging and instream vegetation cover at Gifkloof could partly explain this.

The captured fish generally appeared to be in good physical condition and only one *L. aeneus* specimen was recorded with anomalies.

Three exotic fish species, the common carp *Cyprinus carpio*, grass carp *Ctenopharyngodon idella* and the mosquito fish *Gambusia affinis* have been recorded at Boegoeberg by Kotze and Koekemoer (2010). Although *C. carpio* is known to be present in this part of the river, albeit in low numbers (Benade, 1993), *C. idella* and *G. affinis* have been recorded for the first time.

17.5.4 Macroinvertebrates (B EC, 83.2%)

Macroinvertebrates were sampled using the standard SASS5 method. Habitat available was Stones in current (SIC), Stones out of current (SOOC), Marginal Vegetation in current (MVIC), Marginal vegetation out of current (MVOOC), Gravel and sand (GS). No mud was sampled and no aquatic vegetation was present at site. For list of families present in samples please refer to Table 2.6.

SASS results:

Nov 2010: SASS5 score: 134 (A category[2])	No of Taxa: 22	ASPT: 6.1
May 2010[3]: SASS5 score: 116 (A/B category[1])	No of Taxa: 20	ASPT: 5.8

[2] Category according to Dallas (2007).
[3] Palmer (*pers. comm*.) Boegoeberg sample May 2010 as part of Intermediate Reserve for Orange River Study.

Key taxa expected but not observed were generally those that prefer no to low flow and vegetation namely Gerridae, Hydrometridae, Nepidae and Protoneuridae. Flow at the site even in the vegetation was mostly moderate to high. Very few areas of low to no flow were present at the site. Prosopistomatidae that prefer very high flow and cobbles were also not sampled. This family is difficult to sample and also relatively scarce so their absence in the sample could be due to sampling error. The abundance of most macroinvertebrates at the site was as expected.

17.5.5 Riparian vegetation (D EC, 51.2%)

The present ecological state "**D**" is described as "*Seriously modified. A large loss of natural habitat, biota and basic ecosystem functions has occured"* (Kleynhans *et al*., 2007a). That is indeed the first impression at arrival on the site and a true reflection of the data analysis.

Marginal Zone:

The marginal zone was more easily identified than the lower Zone. This zone can be described as a narrow band on the bank of the river, with *C. dactylon,* and *P. australis* patches. The most dominant tree was *S. mucronata* (Figure 17.5).

Figure 17.5 The marginal zone indicated by the black and white arrows (Photo taken: 2/11/2010)

Lower Zone:

The lower zone was more distinguishable by geomorphological characteristics and plant structure, than plant species composition. This zone was characterized by shrubs, *D. lyciodes,* and *P. grandulosa*, an aggressive invasive tree, as well as a clump of *Equisetum ramosissimum* (Perdestert) and *Psilocaulon coriarium*, the only succulent in this zone. The most dominant grass was *Stipagrostis uniplunis* (Figure 17.6).

Figure 17.6 The lower zone, with *P. grandulosa* as the most dominant tree in the photo (Photo taken: 2/11/2010)

Upper Zone:

The most dominant trees in the upper zone (Figure 17.7) were: *P. grandulosa, Ziziphus mucronata, Acacia karoo, A. mellifera, Searcia pendulina* and *Tamarix usneoides.* It is important to note that most dominant species was *P. grandulosa*, the rest of the trees were individuals occurring on the site. Grasses that occurred were: *S. uniplunis, Aristida ciliata* and *Brachiaria eruciformis*, with *Stipagrostis* being the most dominant. No annuals were noted. The rainy season has not started by the time the site visit was conducted.

Figure 17.7 The end of the upper zone and start of the terrestrial zone (Photo taken: 2/11/2010)

17.5.6 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 17.7.

CAUSE: A stressor that occurs at an intensity, duration and frequency of exposure that results in a change in the ecological conditions.
SOURCE: A source is the origin of a stressor. It is an entity or action that releases or imposes a stressor into the waterbody (EPA, 2000).

Table 17.7 OSAEH 26.17: Causes and sources

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
Rip veg	D	4.6	Exotic invasion	With *P. glandulosa* being the dominant species in the riverine plant community, it will be difficult for indigenous trees to colonise this habitat without human intervention. *Propopis* is particularly tolerant to drought, and resprout easily when damaged. The most important issue is the issue of scale. The scale at which this invader has already invaded not only riparian habitats but also the adjacent terrestrial zone, is enormous.	NF	4
			Irrigation farming	Crops are planted on the edge of the riparian zone, increasing the erosion potential and the amount of pesticides that will enter the river.		
Fish	B/C	4	Change in seasonality of the flow regime could influence spawning reproduction (of e.g. *L. kimberleyensis*).	River regulation has leveled out seasonal differences in the total annual flow and changed character of seasonal floods.	F	2.5
			Changes in the natural structure of fish community due to increased flow during dry season.	River regulation has increased flow in the dry season and practically eliminated periods of flow intermittence.	NF	
			Temperature regime altered downstream of dam and weirs.	Presence of Boegoeberg Dam and a number of other weirs.		
			Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.			
Inverts	B	3.5	Decreased flows during wet season and increased dry season flow as well as a change in the seasonality (winter and summer flows are not as distinct as before dams were built upstream).	Dams and weirs upstream.	F	2
			Loss of habitat due to decrease in flow.			
			Water quality and associated benthic growth.	Agriculture. Increase in nutrients as result of irrigation.	NF	

1 Flow related 2 Non flow related

17.6 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 17.8.

Table 17.8 OSAEH 26.17: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Rip veg	D	Negative	D/E	Long term	It is highly possible that *Prosopis* can even increase more, becoming a monoculture, with no indigenous trees. *Prosopis* may also have a negative effect on the water quantity. Harvesting of indigenous trees might accelerate this process. It is not seen as a problem at the site, at the moment, but the potential exist. Farming takes place almost on the riverbank itself. With bad land management practices, erosion may occur, resulting in higher run-off potential. Higher run-off may result in more nutrients reaching the river and influencing water quality downstream. The buffer capacity of the riparian zone might become impaired.	4
Fish	B/C	Stable			The fish community of the middle Orange has been subjected to the regulated flow regime for more than 30 years and should be stable under these circumstances.	2.5
Inverts	B	Stable			The macroinvertebrates have already reacted to the current conditions. Flow types and habitat availability has changed from natural but most invertebrates are still present.	3

17.7 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 17.9. The Instream EC is a B/C (81.7%).

Table 17.9 OSAEH 26.17: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	4	100		
2.What is the natural diversity of **fish** species with a preference for different cover types	3	80		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	4	90		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2	60		
FISH ECOLOGICAL CATEGORY	13	330	**79.5**	**B/C**
MACROINVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	3	75		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	3.5	90		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	4	100		
AQUATIC INVERTEBRATE ECOLOGICAL CATEGORY	**10.5**	265	83.2	**B**
INSTREAM ECOLOGICAL CATEGORY (Excl confidence)		595	**81.7**	**B/C**

INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	Confidence rating	Proportions	Modified weights
Confidence rating for **fish** information	4	0.53	42.40
Confidence rating for **macroinvertebrate** information	3.5	0.47	38.83
	7.5	1.00	81.23
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**B/C**

To determine the EcoStatus, the VEGRAI EC and confidence is included in the EcoStatus assessment index (Table 17.10). The EcoStatus EC is a C.

Table 17.10 GIFKLOOF: Instream EC

RIPARIAN VEGETATION	EC %	EC
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**51.2**	**D**

ECOSTATUS	Confidence rating	Proportions	Modified weights
Confidence rating for instream biological information	3.76667	0.48	39.39
Confidence rating for riparian vegetation zone information	4	0.52	26.37
	7.76667	1.00	65.76
ECOSTATUS	**EC**		**C**

17.8 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised in Table 17.11.

Table 17.11 OSAEH 26.17: EcoClassification results

Driver Components	PES	Trend
IHI: INSTREAM	C	
IHI: RIPARIAN	C/D	
DIATOMS (WQ)	B/C	
Response Components	**PES**	**Trend**
FISH	B/C	Stable
MACRO INVERTEBRATES	B	Stable
INSTREAM	B/C	
RIPARIAN VEGETATION	D	Negative
ECOSTATUS	C	

17.9 SUITABILITY AS FUTURE MONITORING SITE

17.9.1 Biotopes present

Habitat at the site is moderate to good (3.1 rating) for SASS sampling although the biotope availability according to the SASS5 template (attached as appendix) indicates a poor (D) category. Habitat was restricted at the time of sampling as a result of lower flow than normal for November (DWA official - pers. communication). Depending on flow at time of sampling most biotopes and flow types would be present. Marginal habitat is restricted mostly to reeds and very little grass. No aquatic vegetation was present at time of sampling. Gravel/sand and mud are available during normal flow.

Access to site is good – permission has to be obtained from Stanley at 054 334 0067 and a DWA official has to accompany you to site.

17.9.2 Site suitability

The site suitability of each site was assessed and is provided in Table 17.12. All scores are out of 5 with 5 referring to very high suitability (see below).

Very High: 4.1 – 5 High: 3.1 – 4
Moderate: 2.1 – 3 Low: 1.1 – 2
Very Low: 0 – 1

Table 17.12 GIFKLOOF: Biophysical site suitability

Site	Rip veg	Fish	Inverts	Average	Median	Max	Min	Comments
OSAEH 26.17	2.1	3	3.1	2.7	3	3.1	2.1	**Moderate** to high suitability for EcoClassification for all indicators.

18 OSAEH 28.5: SENDLINGSDRIFT (ORANGE RIVER)

18.1 SITE DESCRIPTION

Location	Sendlingsdrift	**Altitude**	54 m
	Situated at confluence with the Boom River, upstream of D8ORAN-SENDD and D8ORAN-SENDU.		
Longitude	17° 4.400	**Latitude**	28° 2.062
EcoRegion	Orange River Gorge 28.01	**Quaternary catchment**	D82K
Water Management Area	Lower Orange River	**Geomorphological zone**	Lowland River
Management Resource Unit	DS of MRU F	**Natural Resource Unit**	E

Site OSAEH 28 5 is situated approximately 130 km downstream of Vioolsdrift Weir (Figure 18.1) in the lower section of the Orange River (downstream of Augrabies Falls to the estuary) where the river flows through the Orange River Gorge EcoRegion. The site is located in the Orange River mainstem, at the exact point where it is joined by the south flowing Boom River. The Boom River was however dry at the time of sampling, and no pools or other surface water were evident. The geomorphic features of this section of the Orange River channel resemble that of a Lowland river.

The site, at the time of sampling, was dominated by riffles and rapids with slower-flowing habitat occurring upstream and downstream of these. The macro-channel width was >100 m and the active channel and surface water width was 50 – 100 m. Various habitat types were available for macroinvertebrates at the site namely stones in current (rapids and riffles, see Figure 18.2), marginal vegetation (Figure 3.3) and gravel, sand and mud (Figure 18.3). The substratum was mostly bedrock, boulders, cobbles and pebbles and gravel, limited sand and mud. Some stones (especially those in areas of lower flow) were covered with a thickish layer of diatoms and sediment. Flow at the site varied from low (0.03 m/s) to very high (0.85 m/s) in the rapid riffle section and low (0.1 m/s) to high (0.63 m/s) in the marginal vegetation. A small area of aquatic vegetation was present with a flow of 0.1 m/s (low). Flow in gravel/sand/mud biotope varied from 0.1 m/s (low) to 0.24 m/s (moderate).

Figure 18.1 Vioolsdrif weir (D8H003) situated approximately 130 km upstream of site

(Photo from http://www.dwa.gov.za/Hydrology/CGI-BIN/HIS/CGIHis.exe/Photo?Station=D8H003)

Figure 18.2 Rapids and Riffles at Sendelingsdrift

Figure 18.3 Marginal vegetation at Sendelingsdrift

Figure 18.4 Gravel, Sand and Mud at Sendelingsdrift

18.2 BIOTIC SAMPLING

18.2.1 Fish

A river section of approximately 100 m long, comprising a sequence of pool, rapid, run, riffles and run, was surveyed for fish. Five points were sampled at the site in order to cover as much of the available habitat types as possible. A description of each sampling point is presented in Table 18.1, while an assessment of the fish cover available at each sampling point is presented in Table 18.2. An additional point was sampled at the downstream of Sendelingsdrift at a Public Participation (PR)-site (28° 4.432S; 16° 59.633E). Although the purpose of that sampling was to provide information and to demonstrate the fishing techniques used, the results were also considered in the calculation of the FROC and FRAI.

Table 18.1 Description of the various sampling points surveyed at the Sendelingsdrif site. (SD, Slow deep; SS, Slow shallow; FD, Fast deep; FS, Fast shallow; Habitat types based on the definition of Kleynhans, 1999)

Sampling point	Description	Sampling method and effort*
1	Deep slow-flowing pool area (predominantly SD) over a substrate of sand and cobbles along the right bank of the river and upstream of the rapid and riffle areas. Water depths between 36 cm and 102 cm (mean depth 71 cm) were recorded; no surface flow detected by flow meter. Fish cover comprised mainly overhanging vegetation and substrate cover.	Electroshocking (wading) 7 min
2	Very shallow pool area (SS) along the right bank of the river and upstream of the rapid and riffle areas. Depths measured varied between 11 cm and 31 cm (mean depth 22.2 cm) with watergrasses and cobbles providing fish cover.	Electroshocking (wading) 3 min*
3	SS and SD habitat over bedrock, boulders and gravel in the middle of the river channel upstream of the rapid and riffles. Water depths varied between 21 cm – 75 cm (mean depth 49.3 cm). Fish cover mainly provided by the substrate.	Electroshocking (wading) 12 min
4	A riffle area comprising predominantly FS habitat over bedrock, small and large cobbles. Depths ranged between 21 cm and 65 cm (mean depth 36.35 cm). Substrate cover predominated.	Electroshocking (wading) 20 min
5	A rapid approximately 16 m long. FD and FS habitat over a substrate of bedrock, boulders and cobbles. Depths between 20 cm and 57 cm were measured (mean depth 32.5 cm). Surface flow varied between 0.271 m/s and 0.832 m/s (mean velocity 0.550 m/s). Fish cover provided mainly by the substrate.	Electroshocking (wading) 11 min
6	SS and SD habitat over bedrock and boulders. Substrate cover predominant.	Electroshocking (wading) Approximately 15 min

*Sampling effort at the site was limited at the site due to PR obligations.

Table 18.2 Fish habitat assessment (0, absent; 1, rare; 2, sparse; 3, common; 4, abundant; 5, very abundant; based on the description of Kleynhans 1999)

Velocity-depth class	SLOW DEEP					SLOW SHALLOW					FAST DEEP					FAST SHALLOW				
Sampling points	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
ABUNDANCE	4	1	4	2	2	2	4	3	2	1	0	0	1	3	3	0	0	1	4	4
Overhanging vegetation	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Undercut banks and root wads	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Substrate	2	4	4	5	5	3	4	4	3	3	0	0	4	5	4	0	0	4	5	4
Aquatic vegetation	2	2	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Column	3	1	3	3	2	1	1	1	0	0	0	0	2	2	2	0	0	0	1	1

18.2.2 Riparian vegetation

In selecting the sampling site, preference was given to more ideally suited habitats for the macroinvertebrates and fish, than the riparian vegetation. The vegetation assessment was done in a part of the riparian vegetation that was most representative of the riparian vegetation along the river in that area. A suitable sample plot for the riparian vegetation was located as close as possible to the habitats that were selected by the macroinvertebrate and fish specialists. The size of the plot was determined by the surface area that would include the most diagnostic and dominant species present for this part of the Lower Orange River.

Delineation of the riparian zone:
As part of the VEGRAI methodology (Kleynhans *et al*, 2007a), three different zones in the riparian habitat should be delineated. The lateral borders of the site were determined by the surface area in which no more new species could be identified. The longitudinal borders included the Marginal, Lower and Upper Zones.

18.3 DATA AVAILABILITY

The fish data used to calculate the Present Ecological State (PES) of the fish community originated from three fish surveys conducted in the lower Orange River between May and November 2010 (see Table 18.3). These surveys were mainly done at three sites, namely Vioolsdrif (Kotze and Koekemoer, 2010), Orange-Boom confluence (OSAEH 28.5) and Sendelingsdrift–PR site (this study) – all of which are situated in the Natural Resource Unit (NRU) E that stretches from downstream of the Augrabies Falls to Orange River mouth (see WFA, 2010a). The sites are also situated in the same Level II EcoRegion and geomorphic zone (Lowland river).

The Macroinvertebrate data from samples mentioned in Table 18.3 were used to determine the Present Ecological State (PES) category for the OSAEH 28.5). Dallas (2007) SASS interpretation guidelines as well as the MIRAI method were used. Detailed information regarding available data is provided in Table 18.3.

Table 18.3 OSAEH 28.5: Summary of data availability

Comp	Data availability	Conf
IHI	Google Earth imagery. **Orange Senqu River Commission** (ORASECOM). 2008. Preliminary Transboundary Diagnostic Analysis. Main Report. ORASECOM. **WFA**. 2010b. Assessment of Environmental Flow Requirements. Work package 5. Deliverable 10: Resource Unit Delineation Rivers4Africa. Pretoria. **Louw, D**. 2010. IHI results from Intermediate Reserve on Orange River **Department of Water Affairs and Forestry (DWAF), South Africa**. 2004. Internal Strategic Perspective: Lower Orange Water Management Area. Prepared by PDNA, WRP Consulting Engineers (Pty) Ltd, WMB and Kwezi-V3 on behalf of the Directorate: National Water Resource Planning. DWAF Report No P WMA 14/000/00/0304.	3
Riparian vegetation	Google Earth imagery form November 2006. Data collected from field assessment in November 2010. **Cornell F.C.** 1921. The lower reaches of the Orange River. Read at the Meeting of the Society, 24 January 1921. *The Geographical Journal*. Vol LVII, No 4. **Kleynhans C.J., MacKenzie J., Louw M.D**. 2007a. Module F: Riparian Vegetation Response Assessment Index in River Classification: Manual for EcoStatus Determination (version 2). Joint Water Commission and Department of Water Affairs and Forestry report. WRC Report No. TT333/08 **Le Roux A.** 2005. Namaqualand. South African Wild Flower Guide 1. Third Revision. National Botanical Society of South Africa, Cape Town. **Low B.A., Rebello A.G.** (eds) 1998. Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria **Mucina L. & Rutherford M.C**. (eds) 2005. VEGMAP. Wall Map South African National Biodiversity Institute, Pretoria. **Mucina L. & Rutherford M.C**. (eds) 2006. Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19*. South African National Biodiversity Institute, Pretoria. **Van Wyk B. & Van Wyk P**. 2009. Field Guide to trees of Southern Africa. 12th Impression. Struik Nature Publishers, Cape Town.	4.5
Fish	One site visit and fish sampling at the Orange-Boom confluence (OSAEH 28 5) and Sendelingsdrift PR site in November 2010. A fish survey at Vioolsdrift in May/June 2010 by P. Kotze and J. Koekemoer (see Kotze & Koekemer, 2010).	4
Inverts	Once off survey at OSAEH 28 5 (in NRU E and downstream of MRU F identified by WFA, 2010a) to determine PES on 4 November 2010. Data collected by schoolchildren using mini-SASS on 4 November 2010 at site approximately 9 km downstream of OSAEH 28 5 and downstream of MRU F identified by WFA (2010a). Data from Palmer (*pers. comm.*) all in Lowland River and EcoRegion 28.01 at Blouputs (same NRU E but in MRU E – upstream of MRU F) and Vioolsdrift site (EFR O4) (in same NRU E and in MRU F) in 2010.	4

18.4 REFERENCE CONDITIONS

The reference conditions for the components are summarised in Table 18.4. Additional information on fish, macroinvertebrate and riparian vegetation reference conditions are also provided.

Table 18.4 OSAEH 28.5: Reference conditions

Comp	Reference conditions	Conf
IHI	The Reference Habitat Integrity at the site was determined using: Google Earth imagery. **Cornell, F.C. 1921.** The Lower Reaches of the Orange River. *The Geographical Journal* 57(4): 241-252. **DWA. 2009.** Development of an Integrated Water Quality management Strategy for the Upper and Lower Orange Water Management Areas. Report No 2.2 (P RSA D000/00/7909/3). Department of Water Affairs, Pretoria. **ORASECOM. 2007**. Orange River Integrated Water Resources Management Plan. Set of 12 reports. Orange Senqu River Commission. **Heath, R. & Brown,** C. 2007. Orange River Integrated Water Resources Management Plan. Environmental Considerations Pertaining to the Orange River. Orasecom Report No 005/2007. Orange Senqu River Commission. **DWA, 2004**. National water Resource Strategy. Appendix D: Lower Orange River. Department of Water Affairs, Pretoria. **DWAF, 1998a.** Orange River Development Project. Replanning Study. Hydrology and System Analysis – Orange River Basin. Department of Water Affairs & Forestry. Pretoria. **DWAF, 1998b**. Orange River Development Project – Replanning Study. Water Quality Aspects. Orange River Basin: Volume 1: Expected Water Quality Changes. Department of Water Affairs & Forestry. Pretoria. **DWAF, 1999.** Orange River Development Project Replanning Study. Main Report. Department of Water Affairs & Forestry. Pretoria. **Benade, B**. 1993. Studies on the fish populations in the regulated Orange River system within the borders of the Cape Province Volume 1: Text. Unpublished MSc degree, Department of Zoology and Entomology, University of the Free State.	2.5
Rip veg	**Marginal zone:** A mixture of grass, mainly *Cynodon dactylon*, some sedges and reeds are expected. The main tree species, *S. mucronata* and *Tamarix usneoides*. **Lower zone:** The lower zone is expected to host more tree species, especially *Acacia* and some shrubs, as well as annuals and grasses after rain or floods that would increase the soil moisture in the wetbank. **Upper zone:** This zone was dominated by *T. usneoides* and it is assumed that this was the case for the last 50 years at least.	3
Fish	**Kleynhans, C.J., Louw, M.D & Moolman, J**. 2007b. Module D (Volume 2): Reference Frequency of Occurrence of Fish Species in South Africa: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry Report. WRC Report No. TT330/08. Water Research Commission, Pretoria, South Africa. **South African Institute of Aquatic Biodiversity** (SAIAB) data base (2006). **Benade, C.** 1993. Studies on fish populations in the regulated Orange River system within the borders of the Cape Province. Unpublished M.Sc. dissertation, University of the Free State, Bloemfontein: 185 pp. **Cambray, J.A**. 1984. Fish populations in the middle and lower Orange River, with special reference to the effects of stream regulation. *J. Limnol. Soc. Sth. Afr.* 10(2): 37-49. **Cambray, J.A.** 1985. Observations on spawning of *Labeo capensis* and *Clarias gariepinus* in the regulated lower Orange River, South Africa. *South African Journal of Science* 81: 318-321. **de Moor I.J. & Bruton M.N.** 1996. Alien and translocated aquatic animals in southern Africa. *Ann*. *Cape Prov. Mus. (Nat. Hist.)* 19(6). **Gaigher, I.G., Hamman, K.C.D. and Thorne, S.C**. 1980. The distribution, conservation status and factors affecting the survival of indigenous freshwater fishes in the Cape Province. *Koedoe* 23: 57-88. **Jubb, R.A.** 1972. The Hendrik Verwoerd Dam and Orange River fishes. *Piscator* 84: 22-26. **Jubb, R.A. & Farquharsan, F.L**. 1965. The freshwater fishes of the Orange River drainage basin. *South African Journal of Science* 61: 118-145. **Næsje, T.F., Hay, C.J., Nickanor, N., Koekemoer, J., Strand, R. and Thorstad, E.B**. 2007. Fish populations, gill net catches and gill net selectivity in the lower Orange River, Namibia, from 1995-2001. NINA Report 231: 81 pp. **Okeyo** (Unknown): Biodiversity and distribution of freshwater fish of Namibia. Available at : ftp://ftp.cordis.europa.eu/pub/inco2/docs/19_dookeyo.pdf. Accessed on 22 November 2010. **Seaman, M.T. and van As, J.G**. 1998. The environmental status of the Orange River Mouth as reflected by the fish community. Water Research Commission Report Number 505/1/98. 73 pp. **Skelton, P.H. and Cambray, J.A.** 1981. The freshwater fishes of the middle and lower Orange River. *Koedoe* 24: 51-66. **Skelton, P.H.** 1986. Fish of the Orange-Vaal system. In: Davies, B.R. and Walker, K.F. (eds). The ecology of river systems. Dr W. Junk Publishers, Dordrecht: 143-161. **Skelton, P.H.** 2001. A complete guide to the freshwater fishes of southern Africa. Southern Book Publishers, Halfway House. See Table 3.5 for a list of the reference fish species.	3

Comp	Reference conditions	Conf
Inverts	Reference conditions are based on professional judgment and **Agnew, A.D**. 1965. A note on the fauna of the Lower Orange River. *The South African Journal of Science.* 61(3): 126-128. **Biobase** database as well as **River Health** database available at http://www.riv.co.za/Rivers/Application/Login.aspx?ReturnUrl=%2fRivers%2fApplication%2fDefault.aspx was also consulted. **Curtis, B, Roberts, K.S., Griffin, M., Bethune, S., Hay, C.J. & Kolberg, H**. 1998. Species richness and conservation of Namibian freshwater macro-invertebrates, fish and amphibians. *Biodiversity and Conservation* 7: 447-466. **Curtis, B.A**. 1991. Freshwater macro-invertebrates of Namibia. *Madoqua* 17(2): 163-187. **De Moor, F.C. & Car,** M. 1986. A field evaluation of *Bacillus thuringensis* var *israelensis* as a biological control agent for Simulium chutteri (Diptera: Nematocera) in the middle Orange River. *Journal of Veterinary Research* 53: 43-50 (Data available on Biobase database). **Palmer, R.W.** 1996. Invertebrates of the Orange River with emphasis on conservation and management. *South African Journal of Aquatic Science* 22(1/2): 3-51. **Palmer, R.W.** 1997. Changes in the abundance of invertebrates in the stones-in-current biotope in the middle Orange River over five years. Water Research Commission Report No KV130/00. **Dallas, H.F.** 2007. River Health Programme. South African Scoring System (SASS) data interpretation guidelines. Prepared for the Institute of Natural Resources and Department of Water Affairs and Forestry. The reference SASS5 score for the Orange River Gorge Lower EcoRegion is 115 and the ASPT is 5.8 (Dallas, 2007). It must be noted however that only a few samples (mostly post Gariep and Vanderkloof Dams) were used to determine the reference in the Orange River Gorge as very little data is available in this EcoRegion. A reference set in the Macroinvertebrate FROC database (not final and available from Christa Thirion at the DWA: RQS) as part of the MIRAI method is: SASS5 = 180 and ASPT = 6 for OSAEH 28.5. See Table 3.6 for a list of reference macroinvertebrate species.	3.5

18.4.1 Fish

In the context of this report, reference conditions refers specifically to the fish species present in a particular river reach and their FROC under reference habitat conditions (Kleynhans *et al.,* 2007b). The reference conditions set here should be valid for the entire NRU E that comprises the stretch of river downstream of Augrabies Falls to just upstream of where the estuary starts. Please note that a MRU could not be assigned to the site as the delineation of MRUs was only done up to the Fish-Orange confluence. See WFA (2010a) for further details.

The reference conditions set for the Macro-site, D8ORAN-SENDE (Kleynhans *et al*., 200b), was used as a starting point for setting reference conditions for the present site. D8ORAN-SENDE is situated approximately 20 km downstream of where the Boom River joins the Orange River and falls within the same geomorphic zone, EcoRegion and NRU. This reference species list was updated for the present study using a number of literature resources (listed in Table 18.4), together with professional judgement. The following alterations were made to the original list:

- *B. trimaculatus* and *B. paludinosus* was added to the list based on evidence that these species have been previously sampled in close vicinity of the present site. The presence of *B. paludinosus* has been confirmed by *i.a.* Skelton and Cambray (1981), Cambray (1984), Skelton (1986), Benade (1993) and Næsje *et al*. (2007) that of *B. trimaculatus* by Skelton and Cambray (1981), Cambray (1984), Skelton (1986), Benade (1993), SAIAB (2006) and Næsje *et al*. (2007). The presence of *B. paludinosus* in the lower Orange River has also been confirmed by Jubb and Farquharsen (1965).
- The cichlid species, *T. sparrmanii* and *P. philander*, have also been added to the list of expected species. The presence of *P. philander* at, and downstream of Vioolsdrift, has been confirmed by Skelton and Cambray (1981), Cambray (1984), Skelton (1986), SAIAB records (2006) and Næsje *et al*. (2007). The species is widespread and abundant in this section of the river (Skelton and Cambray, 1981) and is known to occur as far down as the mouth (Cambray, 1984; Seaman and van As, 1998). It has first been recorded by Skelton and Cambray in 1981 and there is a strong possibility that the species has been favoured

by river regulation and the development of extensive reed beds in the middle and lower Orange (Cambray, 1984). Although fewer records exist for *T. sparrmanii*, it has been recorded downstream of Vioolsdrift by Cambray (1984) and Næsje *et al*. (2007). The species is further known to occur close to the Orange River mouth (Cambray, 1984). It is, however, not abundant, even in its favoured habitat (Skelton and Cambray, 1981; Cambray, 1984; Næsje *et al*., 2007). Competitive exclusion between *T. sparrmanii*, *P. philander* and *Oreochromis mossambicus* has been mentioned as a possible reason for this (Skelton and Cambray, 1981; Cambray, 1984; Skelton, 1986).

- The river sardine, *Mesobola brevianalis*, has also been added to the original reference list. The presence of the species below Vioolsdrif is well-known and has been noted by *i.e.* Jubb and Farquharsan (1965), Gaigher *et al.* (1980), Skelton and Cambray (1981), Cambray (1984), Skelton (1986), Benade (1993), Seaman and van As (1998), Skelton (2001) and Næsje *et al*. (2007) and is also present in the lower parts of the Fish River (Hay, 1991). Benade (1993) has further recorded the species at Sendelingsdrift where sampling for study was also done. The species is described as being widespread and abundant in the lower Orange River (Skelton and Cambray, 1981; Cambray, 1984; Benade, 1993; Næsje *et al*., 2007).
- *A. sclateri*, and endemic species to the Orange River, was added to the list of expected fish species. Although Gaigher et al. (1980) and Skelton (1986) indicated that *A. sclateri* does not occur below Augrabies Falls, its presence in the Orange River downstream of Vioolsdrift has been confirmed by Cambray (1984), Benade (1993) and Næsje *et al*. (2007). The species is not common even in its preferred habitat (Skelton and Cambray, 1981; Benade, 1993) and only 13 specimens have been recorded downstream of Vioolsdrif by Cambray (1984) during his extensive surveys in March 1982 and September 1983. All of these specimens were sampled in rapids with an electro-fisher. The study of Benade (1993) confirmed this scarcity – only six specimens were recorded from approximately 12 tons of fish.
- The widespread *Clarias gariepinus* was also added to the reference list. It is known to occur in the lower Orange River (Gaigher et al., 1980; Skelton, 1986) and has been recorded at and downstream of Vioolsdrif by Skelton and Cambray (1981), Cambray (1984), Benade (1993) and Næsje *et al*. (2007). Despite the species usually being sampled in low numbers, possibly due to gear selectivity, it is believed to be common in its preferred habitat (Skelton and Cambray, 1981; Benade, 1993). Hay (1991) reported *C. gariepinus* to be more abundant in the lower parts of the Fish River than in the lower Orange River and suggested that the pool habitats in the Fish River could be more suitable for the species.
- It was uncertain whether to include *Labeo umbratus* on the reference list. Although Jubb (1967) indicated that *L. umbratus* only occurs above Augrabies Falls, Skelton (1986) indicated that, despite the species being rare, it is present in the lower Orange River. Skelton and Cambray (1981), Cambray (1984), Benade (1993) and Næsje *et al*. (2007) found no evidence that *L. umbratus* occurs below Augrabies Falls. Cambray (1984) noted that *L. umbratus* is not a successful lotic species and found it to be more successful in the secondary tributaries of the system e.g. the Sak River (see Hocutt and Skelton, 1983). Based on this discussion, *L. umbratus* was not included on the reference list for this river section.
- It was also uncertain if the longfin eel *Anguilla mossambicus* should be considered for the reference list. Although Skelton's (2001) guide does not indicate the species to be present in the Orange River system, both Jubb and Farquharsen (1965) and Jubb (1972) mention the species being recorded in the Orange and Vaal Rivers by anglers. It is, however, not

clear how the species reached these rivers (Jubb, 1972) and it was accordingly not included on the reference list.

Eleven indigenous fish species are therefore expected under reference conditions and are listed in Table 18.5.

Table 18.5 OSAEH 28.5: Reference fish species

Expected Reference and Habitat derived FROC of fish at OSAEH 28.5 (Values used in FRAI). Observed species (HIGHLIGHTED)				
Scientific Names	**Common Name**	**Spp abbreviation**	**Reference FROC**	**Derived FROC**
Labeobarbus kimberleyensis	Largemouth yellowfish	BKIM	1	1
Labeobarbus aeneus	Smallmouth yellowfish	BAEN	5	5
Barbus hospes	Namaqua barb	BHOS	4	3
Barbus paludinosus	Straightfin barb	BPAU	3	4
Barbus trimaculatus	Threespot barb	BTRI	4	3
Labeo capensis	Orange River labeo	LCAP	4	5
Mesobola brevianalis	River sardine	MBRE	5	4
Austroglanis sclateri	Rock catfish	ASCL	1	1
Clarias gariepinus	Sharptooth catfish	CGAR	2	2
Pseudocrenilabrus philander	Southern mouthbrooder	PPHI	4	3
Tilapia sparrmanii	Banded tilapia	TSPA	3	3

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

18.4.2 Macroinvertebrates

The reference list of macroinvertebrates for the site at Sendelingsdrift (OSAEH 28 5) was obtained from Christa Thirion at RQS, Department of Water Affairs in Pretoria. The Macroinvertebrate frequency of occurrence reference list has not been finalised as yet but a draft copy is available.

Expert opinion as well as other historical data (indicated in Table 18.4) was used to set up final reference list.

The macroinvertebrate families expected at the site are indicated in Table 18.6 in the reference abundance and FROC columns. The reference abundance was determined by using all available sampling information from sites situated in the same EcoRegion (28.01) and geomorphological zone (Lowland River) as the site to be sampled. In the case of OSAEH 28.5, information from Palmer (2004, 2005); Sekwele (2004, 2005) and Romollo (2008) at D8ORAN-BLOUP (MRU E), D8HORAN-GOODH (MRU E), D8ORAN-ONSEE (MRU E), D8ORAN-PELLA (MRU E), D8ORAN-RICHT (MRU F), D8ORAN-SENDD (MRU F), D8ORAN-SENDU (MRU F), D8ORAN-VIOOL (MRU F) on Riversdatabase (http://www.riv.co.za/Rivers/Application/Default.aspx), was used as well as historical data and articles indicated in Table 18.4. These sites are all situated in same NRU E, EcoRegion (28.01) and geomorphological Zone (Lowland River). Unfortunately very little information (only Agnew, 1965) is available for the period before Gariep and Vanderkloof Dams (prior to 1970) were built and therefore this reference list could be flawed.

Table 18.6 Reference abundance and FROC as well as present abundance (sample taken 2 November 2010) at Sendelingsdrif (OSAEH 28 5) and other relevant sites in the Lower Orange River

Taxon	Ref abunbance	FROC	Pres Abun 1	Pres Abun 2	Pres Abun 3	Pres freq 1
Aeshnidae	**A**	**4**				
Ancylidae	**A**	**4**	B			1

Taxon	Ref abunbance	FROC	Pres Abun 1	Pres Abun 2	Pres Abun 3	Pres freq 1
Atyidae	B	5	B	B	B	5
Baetidae >2spp	B	5	B	C	B	5
Belostomatidae	A	3				
Bulininae	A	3	1			1
Caenidae	B	5	A	A	B	5
Ceratopogonidae	A	4				
Chironomidae	B	5	A	A	B	5
Chlorocyphidae	A	3				
Coenagrionidae	A	5	A			1
Corbiculidae	B	5	A	A	A	5
Corduliidae	A	4				
Corixidae	A	4				
Culicidae	A	2			A	1
Dytiscidae/Noteridae	A	4	A	A		3
Ecnomidae	A	2	A			1
Elmidae	A	4	A	A	A	5
Gerridae	A	5				
Gomphidae	B	5	A	B	B	5
Gyrinidae	A	5	B	B	A	5
Heptageniidae	A	3		1		1
Hirudinea	A	4	B	A	1	5
Hydracarina	A	3				
Hydrometridae	A	1				
Hydrophilidae	A	4				
Hydropsychidae >2spp	B	5	B	B	B	5
Hydroptilidae	A	3				
Lepidostomatidae	A	2				
Leptoceridae	B	5	A	A		2
Leptophlebiidae	A	4	A	A		2
Libellulidae	A	4				
Lymnaeidae	A	3				
Muscidae	A	2		1		1
Naucoridae	A	5	B	A	1	5
Nepidae	A	2				
Notonectidae	A	3				
Oligochaeta	A	5	B	A	A	5
Perlidae	A	3	A	1	A	5
Planorbinae	A	3				
Pleidae	A	2				
Porifera	A	4	A			1
Potamonautidae	A	5	A			1
Simuliidae	B	5	B	C	C	5
Sphaeridae	A	4				
Tabanidae	A	4				
Tipulidae	A	4				
Tricorythidae	A	4	A	C	B	5
Turbellaria	A	2				
Unionidae	A	3				
Veliidae/Mesoveliidae	A	5				

FROC ratings:
0 = absent
1 = present at very few sites (<10%)
2 = present at few sites (>10 - 25%)
3 = present at about >25 - 50 % of sites
4 = present at most sites (>50 - 75%)
5 = present at almost all sites (>75%)

*Red letters indicate families which have not been sampled at site before but which could be expected due to flow and habitat available at site.

Present Abundance 1: Ddata from 4 November 2010 sample at OSAEH 28 5 site.

Present abundance 2: Data from Palmer, *pers. comm*. (2010) sampling at Blouputs in May 2010 approximately 380 km upstream of site but still in same EcoRegion (28.01), geomorphological zone (Lowland River) and NRU E although in a different MRU E (from WFA (2010a).

Present abundance 3: Data from Palmer, *pers. comm*. (2010) sampling at Vioolsdrift in May 2010 approximately 130 km upstream of site but still in same EcoRegion (28.01), geomorphological zone (Lowland River) and NRU E but in a different MRU E (from WFA (2010a).

Pres. Freq: Is according to a scale of 1 - 5 where 1 is low frequency and 5 high frequency of occurrence.

18.4.3 Riparian vegetation

The earliest literature that could be found on the vegetation of Sendelingsdrift, was a presentation done by Cornell, published in 1921. He gave a beautiful description of the vegetation on the banks of the Orange River:

"The actual margin of the river is usually overhung with a beautiful, vividly green species of weeping willow, the huge trunks of which have rotten and fallen over each other through the ages that they have remained undisturbed; there are also several varieties of thorny acacias; high graceful "camel doorns" 40 or 50 feet in height, covered with little yellow blossoms the scent the air with the perfume of English cowslips; big black-barked trees known as "zwaart beis," beautifully foliaged "haak-doorn," bastard ebony, and a host of other trees and bushes."

The Sendelingsdrift site is also situated in the Nama Karoo Biome and the vegetation was firstly described by Acocks as "*Orange River Broken Veld"* in Low and Robello (1998). Hoffman (1988) changed the description to "*Orange River Nama Karoo"* and describes the riparian vegetation as

abundant thickets and he listed the following species as common along the Orange River: *T. usneoides* (Wild Tamarix), *Ziziphus mucronata* (Buffalo Thorn) *and Acacia erioloba* (Camel Thorn). He also mentions that *P. grandulosa* (Mesquite or "Suidwesdoring") and *Rhigozum trichotomum* (Threethorn) are aggressive invaders.

This area now falls within the Succulent Karoo Biome, as described by Mucina and Rutherford (2006). The vegetation on the banks of the Orange River is classified as: AZa 3 Lower Gariep Alluvial Vegetation. The following plants were also listed as important taxa and were also found on the site:

Trees: *Acacia karoo, Euclea pseudebenus, Salix mucronata var. mucronata, Ziziphus mucronata, T.x usneoides*
Tall Shrubs: *Sisyndite spartea*
Reed beds: *P. australis*
Grasses and herblands: *C. dactylon*, *Litogyne gariepina*

Interesting to note is that according to the Google Image (Figure 18.5) it appears as though the tree cover has increased since 2006.

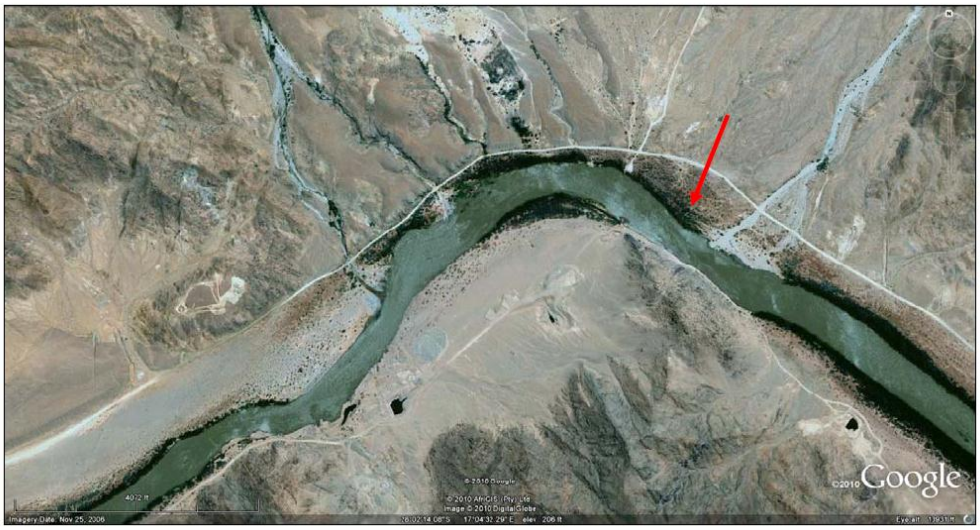

Figure 18.5 This Google Image was taken on 25 November 2006 (Google 2010). The current site is indicated by a red arrow. Although this is a satellite image, it appears as if the tree cover has increased since 2006.

18.5 PRESENT ECOLOGICAL STATE

The component assessment models for the PES are part of the electronic information provided with this report.

18.5.1 Index of Habitat Integrity (IIHI: C EC, 62.4%; RIHI: C EC, 65.7%)

The IIHI is a C (62.4%). This is mostly due to changes in bank and bed due to influence of irrigation upstream as well as change in hydrology and sediment load as a result of large dams (Gariep and Vanderkloof) in Upper Orange River and various weirs upstream. The RIHI is a C (65.7%) with the main impact being added nutrients from irrigation upstream leading to increased growth of reeds etc. as well as change in hydrology affecting plant growth on banks. Some trampling (probably wildlife) was also seen at site.

18.5.2 Fish (B/C EC, 78.8%)

All the expected fish species are still present within this Resource Unit (RU) although the FROC of some species have been reduced from reference conditions. All three IUCN Red Data listed species *L. kimberleyensis* ("near threatened"), *B. hospes* ("least concern") and *A. sclateri* ("least concern") have been found to be still present in the lower Orange River, with only the FROC of *B. hospes* being slightly reduced. The reference FROC for *L. kimberleyensis* and *A. sclateri*, expected to occur at less than 10% of the sampling sites, was mainly based on the data resulting from the extensive surveys of Skelton and Cambray (1981) and Cambray (1984). These surveys were, however, done after the completion of the Boegoeberg, Vanderkloof and Gariep Dams, and it is too a large extent uncertain how the FROCs of these two species have been influenced by the resultant flow regulation. Both these species are however known to be under represented in samples and are possibly more abundant than indicated by sampling data (Skelton, 1986).

Interestingly, the reference FROC of the species usually associated with fast flow and substrate cover (*L. kimberleyensis*, *L. aeneus*, *Labeo capensis* and *A. sclateri*) remained unchanged. A slight decrease in the reference FROC was however recorded for the majority of species associated with slower flowing habitats and overhanging vegetation cover, including *B. paludinosus*, *B. trimaculatus*, *M. brevianalis*, *P. philander* and *C. gariepinus*.

The slight reduction in the FROC of *M. brevianalis*, described by Skelton and Cambray (1981) as the "most common and abundant species below Augrabies Falls", was mainly due to the fact it was not recorded at the Boom-Orange confluence (OSAEH 28 5) and Sendelingsdrif (this study). Kotze and Koekemoer (2010) found the species to be widespread and abundant at Vioolsdrift during their survey in May/June 2010. Habitats hosting overhanging and instream vegetation cover were however rare at the OSAEH 28 5 (Boom-Orange confluence) and Sendelingsdrift sites (see Table 3.2) and could to an extent explain the reduction in FROC for not only *M. brevianalis*, but also for *B. paludinosus* and *P. philander*).

One exotic, *Cyprinus carpio*, and two introduced species, *Oreochromis mossambicus* and *T. rendalli* are known to occur between Vioolsdrift and the mouth (Skelton, 1986; Næsje *et al*., 2007). Of these, *C. carpio* and *O. mossambicus* have been recorded during the recent surveys. Although very few *C. carpio* individuals were recorded, *O. mossambicus* were found to be widely distributed and more abundant. Concern has been expressed by Næsje *et al*. (2007) that the species is becoming increasingly more widespread and abundant in the lower Orange River.

18.5.3 Diatoms (C EC)

Diatom results are based on samples taken during 2005, 2008 – 2010 at various sites situated in the reach below MRU F. The EC for this reach is a C. Nutrient levels are elevated at times with slight levels of pollution.

18.5.4 Macroinvertebrates (B/C EC, 79.12%)

Macroinvertebrates were sampled using the standard SASS5 method. Habitat available was SIC, SOOC, Marginal Vegetation in current (MVIC), Marginal vegetation out of current (MVOOC), Aquatic vegetation in current (AVIC), and GSM.

November 2010 (Sendelingdrif)	SASS5 score: 150	No of Taxa: 24	ASPT: 6.3 (A category[4])
May 2010[5] (Blouputs)	SASS5 score: 133	No of Taxa: 20	ASPT: 6.7 (A category[3])

[4] Palmer (*pers. comm*.) Blouputs and Vioolsdrif sample May 2010 as part of Intermediate Reserve for Orange River Study and Vioolsdrif sample during 2010.

* May 2010[4] (Vioolsdrift) SASS5 score: 96 No of Taxa: 16 ASPT: 6.0 (A category[3])

Key taxa expected but not observed were generally those that prefer no to low flow and vegetation or water column namely Belostomatidae, Corixidae, Culicidae, Gerridae, Hydrophilidae, Hydroptilidae and Planorbinae. Flow at the site even in the vegetation was mostly moderate to high. Very few areas of low to no flow were present at the site. Aeshnidae that prefer any flow and cobbles or vegetation was also not sampled. This could be due to sampling error. The abundance of most macroinvertebrates at the site was as expected.

18.5.5 Riparian vegetation (B EC, 82.4%)

The present ecological state "B" is described as "*Largely natural with few modifications. A small change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged"* (Kleynhans *et al*, 2007a). That is indeed the first impression at arrival on the site and a true reflection of the data analysis.

Marginal Zone:

The marginal zone (Figure 18.6) differed in size along the bank of the river. This zone was distinguished from the lower zone, on the basis of species composition, especially the presence and absence of diagnostic grass and tree species. While the marginal zone was dominated by *C. dactylon* and *S. mucronata*, the lower zone was characterized by an increase in the abundance and cover of trees. The terrain can be described as flat, with sandy soils and almost no rocks.

Figure 18.6 The marginal zone with *Persecaria* sp. in the foreground (Photo taken: 4/11/2010)

Lower Zone:

In comparison to the site at Gifkloof, Upington, the lower zone (Figure 18.7) was more distinguishable in terms of species composition and plant structure, than geomorphological features. The slope gradient from marginal to lower zone is very gradual. The most dominant trees on this zone were: *S. mucronata, T. usneoides, A. karoo and Z. mucronata.* The most abundant grass was *C. dactylon*, with a few individual plants of *Gomphocarpus fruticosus.*

[5] Palmer (*pers. comm*.) Blouputs and Vioolsdrif sample May 2010 as part of Intermediate Reserve for Orange River Study and Vioolsdrif sample during 2010.

Figure 18.7 The lower zone indicated by a red arrow (Photo taken: 4/11/2010)

Upper Zone:

The most dominant tree in the upper zone was *T. usneoides.* The terrain can be described as flat, with sandy soils. Open patches occurred between the trees, as can be seen in Figure 18.7. Most of the annuals were dead, but some were blooming (Figure 18.8). However, it was eminent from the dead plants, that the non-woody cover was good. The rainy season had not started by the time the site visit was conducted. On the edge between the upper and terrestrial zone, *Lycium horridum, Sisyndite spartea* and *Euclea sedibens* occurred. There was also a difference in the structure of *T. usneoides*, as the distance increased from the river. The trees became smaller and their leaf colour also became more dull green. This could be explained by a possible decrease in soil moisture content, as the distance from the river increases.

Figure 18.8 Dominant *T. usneoides* plant community in the upper zone (Photo taken: 4/11/2010)

The non-woody component (Figure 18.9 and 187.10) was represented by *Atriplex semibaccata, L. gariepina, Jamesbrittenia sp.* and one species of the Mesembryanthemaceae family that could not be identified. This specimen was prepared by Dr Andor Venter of the Geo Potts Herbarium, University of the Free State, Bloemfontein, for identification by the Pretoria National Herbarium.

Figure 18.9 Non woody plants in the upper zone: *Atriplex semibaccata* and unknown member of the Mesemb family

Figure 18.10 Non woody plants in the upper zone: *Jamesbrittenia sp.* and *L. gariepina*

18.5.6 PES causes and sources

The PES for the components as well as the reasons for the PES are summarised in Table 18.7.

Table 18.7 OSAEH 28.5: Causes and sources

	PES	Conf	Causes	Sources	F/NF	Conf
Rip veg	B	4.1	Vegetation removal.	The marginal zone showed some signs of grazing. How recent, is difficult to say. It is also assumed that natural recovery after grazing pressure, will take longer due to the arid environment.	NF	4
			Water quantity.	According to personal communication with Mr Piet Wessels (19/11/2010) and Mr James MacKenzie (17/11/2010), the water level is slightly higher than expected since water releases from the upstream dams are more than the natural flow would have been.	F	
Fish	B/C	3	Loss of habitat (decreased SD and SS) diversity as a result of flow modification (especially during natural low flow periods).	River regulation has leveled out seasonal differences in the total annual flow and removed periods of intermittence in the lower Orange.	F	2.5
			Change in seasonality of the flow regime could influence spawning reproduction as well as natural community structures.	River regulation has reduced seasonal differences of the total annual flow. Natural cessations of flow removed by regulation.		
			Decreased substrate quality related to increased benthic growth.	Return flows from irrigated agricultural areas.		
			Decrease in the condition of species moderately intolerant to modified water quality (e.g. *L. kimberleyensis*).	Return flows from irrigated lands downstream of Vioolsdrift to the river. The introduced *O. mossambicus* is becoming		

	PES	Conf	Causes	Sources	F/NF	Conf
			Decrease in species diversity and abundance as a result of competition between *T. sparrmanii*, P. philander and *O. mossambicus*.	increasingly more widespread and more abundant in the lower Orange.		
			Increased turbidity and disturbed bottom substrates.	Presence of bottom feeding alien *C. carpio*.		
			Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	The weir at Vioolsdrift, as well as the new gauging weir under construction nearby Sendelingsdrift. According to an official from Namibia, a fish ladder is to be built to allow fish migration.		
Inverts	B/C	3.5	Decreased flows during wet season and increased dry season flow as well as a change in the seasonality (winter and summer flows are not as distinct as before dams were built upstream).	Dams and weirs upstream.	F	2
			Loss of habitat due to decrease in flow.			
			Water quality and associated benthic growth.	Agriculture. Increase in nutrients as result of irrigation.	NF	

18.6 PES TREND

An estimate was made whether the components responding to the main drivers (quality and quantity) are stable or still changing. The results are summarised in Table 18.8.

Table 18.8 OSAEH 28.5: Trend

	PES	Trend	Trend PES	Time	Reasons	Conf
Rip veg	B	Stable			Since this section of the river is situated in a protected area, the condition of the river should stay within a B category. The riparian vegetation is already adapted to harsh conditions, so small changes should not affect the condition of the riparian vegetation.	4
Fish	B/C	Slightly negative	C	Long term	The construction of a new gauging weir near Sendelingsdrift could have a negative impact on fish migration. It is however understood that a fish ladder is to be built to allow fish movement. The fish seem to have already adapted to changes in the seasonality and magnitude of floods as most of the species seems to be reproducing.	3
Inverts	B/C	Slightly	B/C	Long term	The macroinvertebrates have already reacted to the current conditions. Flow types and habitat availability has changed from natural but most invertebrates are still present. After the new weir at Sendelingsdrift has been completed downstream of this site some change in the abundances of invertebrates is expected but it is not expected that this would result in a change in the PES category.	3

18.7 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results must be combined to determine an Instream EC. Results are given in Table 18.9. The Instream EC is a B/C (79%).

Table 18.9 OSAEH 28.5: Instream EC

INSTREAM BIOTA	Importance Score	Weight	EC %	EC
FISH				
1.What is the natural diversity of **fish** species with different flow requirements	4	90		
2.What is the natural diversity of **fish** species with a preference for different cover types	3.5	80		
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	4	100		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2	60		

FISH ECOLOGICAL CATEGORY	13.5	330	**78.8**	**B/C**
MACROINVERTEBRATES				
1. What is the natural diversity of **invertebrate** biotopes	4	100		
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	4	100		
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	4	100		
AQUATIC INVERTEBRATE ECOLOGICAL CATEGORY	**12**	300	79.12	**B/C**
INSTREAM ECOLOGICAL CATEGORY (Excl confidence)		630	**79.0**	**B/C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proportions**	**Modified weights**	
Confidence rating for **fish** information	4	0.53	42.03	
Confidence rating for **macroinvertebrate** information	3.5	0.47	36.92	
	7.5	1.00	78.95	
INSTREAM ECOLOGICAL CATEOGORY	**EC**		**B/C**	

To determine the EcoStatus, the VEGRAI EC and confidence is included in the EcoStatus assessment index (Table 18.10). The EcoStatus EC is a B/C.

Table 18.10 OSAEH 28.5: Instream EC

RIPARIAN VEGETATION	**EC %**	**EC**	
RIPARIAN VEGETATION ECOLOGICAL CATEGORY	**82.4**	**B**	
ECOSTATUS	**Confidence rating**	**Proportions**	**Modified weights**
Confidence rating for instream biological information	3.76667	0.48	37.80
Confidence rating for riparian vegetation zone information	4.1	0.52	42.95
	7.86667	1.00	80.75
ECOSTATUS	**EC**		**B/C**

18.8 SUMMARY OF ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised in Table 18.11.

Table 18.11 OSAEH 28.5: EcoClassification results

Driver Components	PES	Trend
IHI: INSTREAM	C	
IHI: RIPARIAN	C	
DIATOMS (WQ)	C	
Response Components	**PES**	**Trend**
FISH	B/C	Negative (B/C)
MACRO INVERTEBRATES	B/C	Negative (B/C)
INSTREAM	B/C	
RIPARIAN VEGETATION	B	Stable
ECOSTATUS	B/C	

18.9 SUITABILITY AS FUTURE MONITORING SITE

18.9.1 Biotopes present

Habitat at the site is good (4 rating) for SASS sampling and the biotope availability according to the SASS5 template indicates a good (B category). All habitat and flow types were present at site. Marginal vegetation was however restricted (only small area available) as most of the bank was either mud or cobbles and pebbles.

Access to site is easy – site is accessed from the Namibian side in the Ai Ais Richtersveld Transfrontier Park. Turn off from road at the Boom tributary and drive in dry river bed to site. If the Boom River is flowing access is still possible from the gravel road travelling from Noordoewer to Rosh Pinah.

18.9.2 Site suitability

The site suitability of each site was assessed and is provided in Table 18.12. All scores are out of 5 with 5 referring to very high suitability (see below).

Very High: 4.1 – 5 High: 3.1 – 4
Moderate: 2.1 – 3 Low: 1.1 – 2
Very Low: 0 – 1

Table 18.12 OSAEH 28.5: Biophysical site suitability

Site	Rip veg	Fish	Inverts	Average	Median	Max	Min	Comments
OSAEH 28.5	3	4	4	3.6	4	4	3	**Moderate** to high suitability for EcoClassification from all indicators

19 SENQU RIVER: QUALITATIVE ASSESSMENT OF SASS 5 DATA

Qualitative data analysis of the macroinvertebrate monitoring data was provided by Dr Eliot Taylor - Principal Consultant and Team Leader, Water Resources Investment Strategy. WS ATKINS International Ltd.

19.1 INTRODUCTION

The Lesotho Highlands Development Authority (LHDA) has been overseeing monitoring of a number of sites across Lesotho to monitor and assess the effectiveness of the Instream Flow Requirements (IFR) set as part of the Lesotho Highlands Development programme that was responsible for the construction of a large number of dams in the kingdom. IFRs were set for these in an attempt to reduce their environmental impact on downstream watercourses.
The dams and monitoring sites are shown in Figure 19.1.

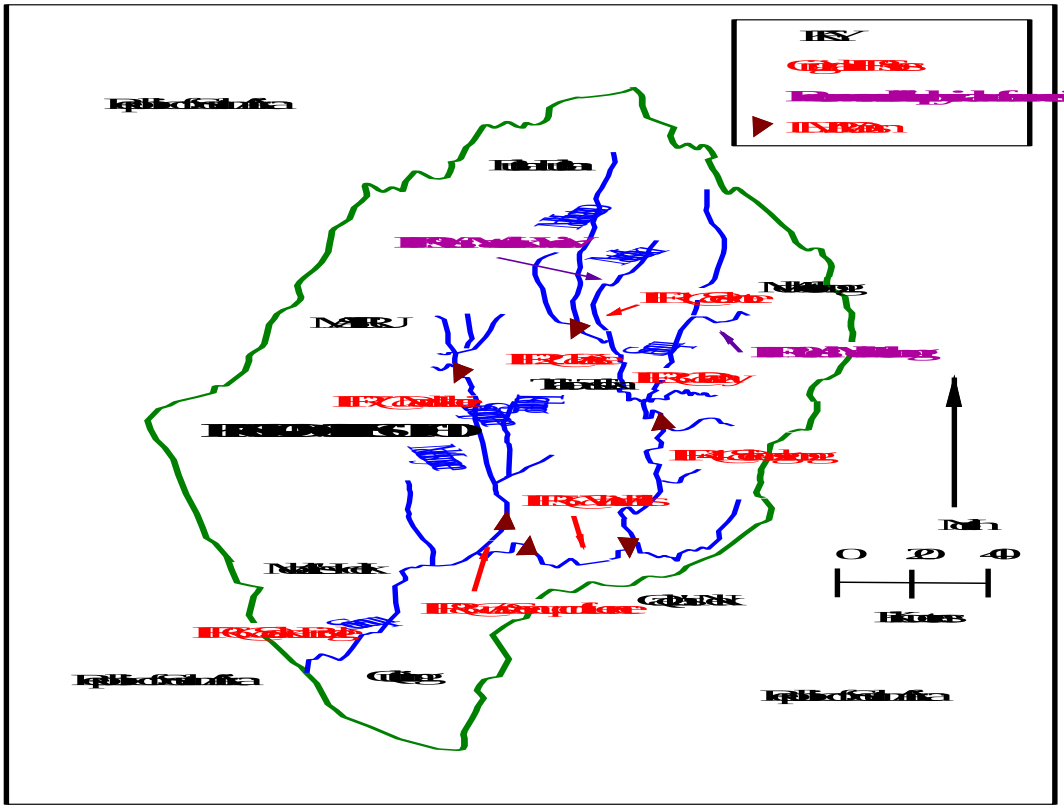

Figure 19.1 Map of Lesotho showing dams and IFR monitoring sites

The following assessment is based on an analysis of the SASS field sheets, modified for IFR monitoring, that were provided by LHDA. SASS and ASPT scores have been calculated for each sample and these scores used to determine Ecological Category based on the SASS Interpretation Guidelines developed by Dallas (2007).

19.2 RESULTS AND INTERPRETATION

19.2.1 IFR 1 – Control site (upstream of any dams) on the Matsoku River

Table 19.1 SASS, ASPT and Ecological Category results for IFR 1 from 2006 - 2010

Site	Date	SASS	ASPT	Dallas		
				EcoCat[6] SASS	EcoCat ASPT	EcoCat overall

[6] Ecological Category defined by Dallas (2007).

Site	Date	SASS	ASPT	Dallas		
				EcoCat[6] SASS	EcoCat ASPT	EcoCat overall
IFR1	04/04/2006	151	5.39	B	D	B
IFR1	17/09/2006	138	5.75	C	C	C
IFR1	13/04/2007	147	5.88	B	C	B
IFR1	10/09/2007	131	5.7	C	C	C
IFR1	10/04/2008	58	4.83	E/F	E/F	E/F
IFR1	05/07/2008	95	5.28	D	D	D
IFR1	13/04/2010	90	5.63	D	C	C

IFR 1 is a control site upstream of, and therefore unaffected by, all the LHDA dam sites. Despite the fact that it is unaffected by the dams, it is still, on average (from all the samples taken at this site since 2006) only a category C site. There has been some variation in category from year to year, with the highest a category B in 2006 and 2007 samples and a category E/F in one of the 2008 samples. With regard to the latter, there appears to have been an (pollution or other) incident in or shortly before April 2008 (results from then show the site as Category E/F) from which the site has been slowly recovering (D in July 2008 and C in 2010) since.

Ecological Category has been reasonably consistent between SASS and ASPT across the years with only one sample (04/04/2006) showing a whole category difference between those derived from ASPT (D) and SASS (B) scores.

19.2.2 IFR2 – Impacted site on the Malibamats'o River immediately downstream of Katse Dam

Table 19.2 SASS, ASPT and Ecological Category results for IRF 2 from 2006 - 2010

Site	Date	SASS	ASPT	Dallas		
				EcoCat SASS	EcoCat ASPT	EcoCat overall
IFR2	04/06/2006	72	4.50	E/F	E/F	E/F
IFR2	15/09/2006	117	5.57	C	D	C
IFR2	13/10/2007	115	5.70	C	C	C
IFR2	04/11/2007	133	5.12	C	D	C
IFR2	10/01/2008	87	5.44	D	D	D
IFR2	05/08/2008	114	6.33	C	B	B
IFR2	14/04/2010*	60	6.67	E/F	B	B

* SASS sheet refers to high flows from dam release day prior to sampling.

IFR 2 is located immediately downstream from Katse Dam. The site appeared to have been adversely affected when monitoring started in 2006 but has been improving consistently since (E/F in 2006, C in 2007 and B in 2008 and 2010) although with a slight decline in early 2008 (10.01/2008).

The Ecological Categories determined for the site by both SASS and ASPT scores have been reasonably consistent with only one sample (14/04/2010) showing two whole categories difference between that derived by ASPT and that by SASS results. For the 14/04/2010 sample, it was recorded on the SASS sheet that the sample was taken the day after high dam release flows from upstream and this may have caused the results shown for this sample.

19.2.3 IFR 3 – Impacted site on the Malibamats'o River further downstream from Katse Dam

Table 19.3 SASS, ASPT and Ecological Category results for IRF 3 from 2006 - 2010

Site	Date	SASS	ASPT	Dallas		
				EcoCat SASS	EcoCat ASPT	EcoCat overall
IFR3	26/04/2006	119	5.67	C	C	C

Site	Date	SASS	ASPT	Dallas		
				EcoCat SASS	EcoCat ASPT	EcoCat overall
IFR3	19/09/2006	134	6.09	C	C	C
IFR3	14/04/2007	156	6.78	B	B	B
IFR3	10/10/2007	150	6.00	B	C	B
IFR3	10/03/2008	113	5.65	C	C	C
IFR3	05/04/2008	136	5.67	C	C	C
IFR3	15/04/2010	87	5.8	D	C	C

IFR 3 is further downstream of Katse Dam than IFR 2; and is also downstream of the confluence of the Matsoku River on which IFR 1 is located. This site shows a very consistent category C score, although with a slight improvement to category B in the 2007 samples.

There is good consistency between the SASS and ASPT derived Ecological Categories.

19.2.4 IFR 4 – Impacted site on the Senqu River downstream of the Katse Dam

Table 19.4 SASS, ASPT and Ecological Category results for IRF 4 from 2006 - 2010

Site	Date	SASS	ASPT	Dallas		
				EcoCat SASS	EcoCat ASPT	EcoCat overall
IFR4	18/09/2006	134	6.7	C	B	B
IFR4	15/04/2007	87	7.25	D	A	A
IFR4	10/02/2008	78	7.09	E/F	A	A
IFR4	05/06/2008	120	6.00	C	C	C
IFR4	16/04/2010	SASS sheet submitted but not completed				

The results of only 4 samples (1 in 2006 and 20077; 2 in 2008; 1 in 2010) were available and although a SASS sheet was provided for 2010, it had not been completed. This lack of data restricts the interpretation that is possible as well as accuracy of this. The site has varied in its overall category since sampling began from an A to C category. There have also been large (2 ecological categories on 15/04/2007 and 3 categories on 10/02/2008) differences between the SASS and ASPT derived ecological categories. It is unclear what is causing these regular shifts in overall category and in the category derived by ASPT and SASS results.

19.2.5 IFR 5 – Impacted site on the Senqu River downstream of the Katse Dam

Table 19.5 SASS, ASPT and Ecological Category results for IRF 5 from 2006 - 2010

Site	Date	SASS	ASPT	Dallas		
				EcoCat SASS	EcoCat ASPT	EcoCat overall
IFR5	21/09/2006	160	6.67	B	B	B
IFR5	19/04/2007	103	7.36	D	A	A
IFR5	10/08/2007	135	7.5	C	A	A
IFR5	30/04/2009	104	8.00	D	A	A
IFR5	04/07/2010	80	6.67	E/F	B	B

The overall Ecological Category for this site is A/B but there have consistently been big differences between the SASS and ASPT derived categories (2 categories in 19/04/2007; 1 in 10/08/2007; 2 in 30/04/20009 and 2 in 04/07/2010). It is not clear why ASPT and SASS show such different categories.

19.2.6 IFR 6 – Most downstream site on the Senqu River

Table 19.6 SASS, ASPT and Ecological Category results for IRF 6 from 2006 - 2010

Site	Date	SASS	ASPT	Dallas		
				EcoCat SASS	EcoCat ASPT	EcoCat overall
IFR6	20/09/2006	120	6.32	C	B	B
IFR6	16/10/2007	101	7.21	D	A	A
IFR6	29/04/2008	53	5.89	E/F	C	C
IFR6	10/06/2008	100	6.25	D	B	B
IFR6	29/04/2009	94	6.27	D	B	B
IFR6	04/10/2010	57	7.13	E/F	A	A

IFR 6 has changed its category between A and C across the sampling period although it is on average a category B site. As with IFR 5, there have been big differences between the ecological category derived using either SASS or ASPT in most samples (2 in 16/10/2007; 1 in 29/04/2008, 10/06/2008 and 29/04/2009 and 3 in 04/10/2010). It is not clear why ASPT and SASS have shown such different categories.

19.2.7 IFR 7 – Impacted site on the Senqunyane River immediately downstream of Mogale Dam

Table 19.7 SASS, ASPT and Ecological Category results for IRF 7 from 2006 - 2010

Site	Date	SASS	ASPT	Dallas		
				EcoCat SASS	EcoCat ASPT	EcoCat overall
IFR7	27/04/2006	157	6.28	B	B	B
IFR7	20/09/2006	167	5.96	B	C	B
IFR7	16/04/2007	158	6.32	B	B	B
IFR7	14/10/2007	154	6.16	B	B	B
IFR7	05/03/2008	136	8.00	C	A	A
IFR7	10/05/2008	116	6.11	C	C	C
IFR7	04/11/2010	111	6.53	D	B	B

IFR 7 has been almost consistently category B since sampling began although it varied from category A to C in 2008. Categories derived by SASS and ASPT have also been relatively consistent with only two of the samples taken (05/03/2008 and 04/11/2010) showing a whole category difference between the two.

19.2.8 IFR 9 – Control site on the Matsoku River upstream of IFR 1

Table 19.8 SASS, ASPT and Ecological Category results for IRF 9 from 2006 - 2010

Site	Date	SASS	ASPT	Dallas		
				EcoCat SASS	EcoCat ASPT	EcoCat overall
IFR9	04/05/2006	134	6.38	C	B	B
IFR9	04/12/2007	155	6.20	B	B	B
IFR9	05/05/2008	118	7.38	C	A	A
IFR9	30/09/2008	114	6.71	C	B	B
IFR9	04/12/2010	93	7.75	D	A	A

IFR 9 is on average category B and the categories derived by both ASPT and SASS scores are reasonably consistent, although there was a 1 category difference in 05/05/2008 sample and 2 in 04/12/2010 sample. The reasons for this are unclear.

19.3 CONCLUSION

The data provided has allowed an interpretation of the overall (average) and year on year ecological category for the sampled sites, with ecological category derived using Dallas (2007).

The data has also allowed to determine the relatively consistency (or otherwise) of ecological category as derived using both SASS and ASPT.

It has not possible from this data alone to provide an explanation of why the category of sites has been as they are, or to propose any reasons for the observed changes over the years. In order to interpret the data more, and to discuss and explore possible reasons for the patterns seen, data on drivers of ecological changes, such as data on flow, habitat and water quality, would be needed.

20 FISH RIVER: QUALITATIVE ASSESSMENT OF SASS 5 DATA

Qualitative data analysis of the macroinvertebrate data was provided by Dr Eliot Taylor - Principal Consultant and Team Leader, Water Resources Investment Strategy. WS ATKINS International Ltd.

20.1 RESULTS

From Dallas (2007):

Ecoregion Level 1	Longitudinal Zone	Sig Diff	N	n	SASS5 Score							ASPT						
					Median	Min	Max	Percentiles				Median	Min	Max	Percentiles			
								90.0	67.5	45.0	22.5				90.0	67.5	45.0	22.5
Nama Karoo	Lower	-	8	25	90	20	132	118	100	76	33	5.3	3.6	6.3	6.0	5.5	5.3	4.7

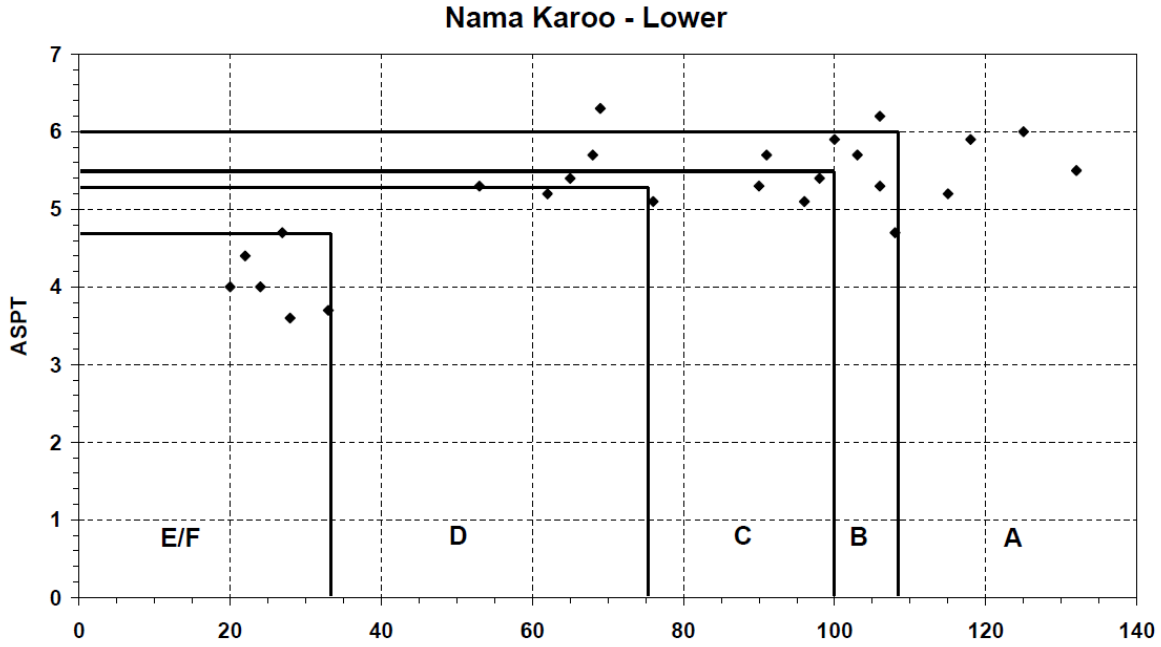

Figure 20.1 Guidelines used to delineation the Present Ecological State Categories in terms of SASS5 biomonitoring results. The delineation was based on a scatter plot of SASS scores from the lower portion of the Nama Karoo EcoRegion

Table 20.1 NASS results for the Fish River

Site	B1 (Neckartal)		B2 (Seeheim)		Combined
Variable	Aug-09	Feb-10	Aug-09	Feb-10	
Flow	trickle	low	zero	low	
Biotope Suitability (%)	29	51	n/a	38	38
NASS2 Score	84	80	n/a	95	86
NASS2 Taxa	14	16	n/a	20	n/a
ASPT	6.0	5.0	n/a	4.8	5.3
Eco-cat (NASS)	C	C	n/a	C	C
Eco-cat (ASPT)	A	D	n/a	D	C

The overall Ecological Category for macroinvertebrates was determined as a C.

Unless there are known sources of pollution, anthropogenically induced changes to flow, habitat structure etc. this result more likely reflects the ephemeral nature of the watercourse and **not** a real category C watercourse. NASS, as with SASS5, just is not designed for use in ephemeral rivers.

21 REFERENCES

AFNOR (2000). Norme Française NF T 90–354. Détermination de l'Indice Biologique Diatomées IBD. Association Française de Normalisation, 63 pp.

Agnew, A.D. 1965. A note on the fauna of the Lower Orange River. *The South African Journal of Science.* 61(3): 126-128.

Battarbee, RW (1986). Diatom Analysis. In Berglund BE (ed) Handbook of Holocene Paleoecology and Paleohydrology. John Wiley & Sons Ltd. Chichester. Great Briton. pp 527-570.

Belcher, T. And Herdien, E. 2009. Freshwater Assessment for the Proposed Improvement of structures along the R27, Section 10 and 11 between Kenhardt and Keimoes. CCA Environmental. Caledon Square.

Benade, C. 1993. Studies on fish populations in the regulated Orange River system within the borders of the Cape Province. Unpublished M.Sc. dissertation, University of the Free State, Bloemfontein: 185 pp.

Bezuidenhout H. & Jardine C.L. 2001. A reconnaissance botanical survey of the Lower Orange River (Blouputs to Onseepkans) in the Northern Cape, South Africa. *Koedoe* 44(1): 1-8. Pretoria.
Biobase database as well as River Health database available at http://www.riv.co.za/Rivers/Application/Login.aspx?ReturnUrl=%2fRivers%2fApplication%2fDefault.aspx.

Bromilow C. 2001. Problem Plants of South Africa. Briza Publications, Pretoria

Cambray, J.A. 1983. Early development and larval behaviour of a minnow, *Barbus anoplus* (Pisces: Cypriniday). *Suid-Afrikaanse Tydskrif vir Dierkunde* 18(4): 331-336.

Cambray, J.A. 1984. Fish populations in the middle and lower Orange River, with special reference to the effects of stream regulation. *J. Limnol. Soc. Sth. Afr.* 10(2): 37-49.

Cambray, J.A. 1985. Observations on spawning of *Labeo capensis* and *Clarias gariepinus* in the regulated lower Orange River, South Africa. *South African Journal of Science* 81: 318-321.
Cornell, F.C. 1921. The Lower Reaches of the Orange River. *The Geographical Journal* 57(4): 241-252.

Cattaneo, A, Couillard, Y, Wunsam, S, and Courcelles, M (2004). Diatom taxonomic and morphological changes as indicators of metal pollution and recovery in Lac Dufault Québec, *Canada. Journal of Paleolimnology* **32**: 163-175.

CEMAGREF (1982) Etude des methodes biologiques quantitatives d'appreciation de la qualite des eaux. Rapport Division Qualité des Eaux Lyon - Agence Financiere de Bassin

Comité Européen de Normalisation (CEN) (2003). Water quality – Guidance standard for the routine sampling and pre-treatment of benthic diatoms from rivers. European Standard. EN 13946:2003.

Curtis, B., Roberts, K.S., Griffin, M., Bethune, S., Hay, C.J. and Kolberg, H. 1998. Species richness and conservation of Namibian freshwater macro-invertebrates, fish and amphibians. *Biodiversity and Conservation* 7: 447-466.

Curtis, B.A. 1991. Freshwater macro-invertebrates of Namibia. *Madoqua* 17(2): 163-187.

Dallas, H.F. 2007. River Health Programme. South African Scoring System (SASS) data interpretation guidelines. Prepared for the Institute of Natural Resources and Department of Water Affairs and Forestry.

De Moor I.J.& Bruton M.N. 1996. Alien and translocated aquatic animals in southern Africa. *Ann. Cape Prov. Mus. (Nat. Hist.)* 19(6).

De Moor, F.C. and Car, M. 1986. A field evaluation of *Bacillus thuringensis* var *israelensis* as a biological control agent for Simulium chutteri (Diptera: Nematocera) in the middle Orange River. *Journal of Veterinary Research* 53: 43-50 (Data available on Biobase database)

Department of Water Affairs and Forestry (DWAF), 1998a. Orange River Development Project. Replanning Study. Hydrology and System Analysis – Orange River Basin. Department of Water Affairs & Forestry. Pretoria.

Department of Water Affairs and Forestry (DWAF), 1998b. Orange River Development Project – Replanning Study. Water Quality Aspects. Orange River Basin: Volume 1: Expected Water Quality Changes. Department of Water Affairs & Forestry. Pretoria.

Department of Water Affairs and Forestry (DWAF), 1999. Orange River Development Project Replanning Study. Main Report. Department of Water Affairs & Forestry. Pretoria.

Department of Water Affairs and Forestry (DWAF), South Africa. 2004. *Internal Strategic Perspective: Lower Orange Water Management Area*. Prepared by PDNA, WRP Consulting Engineers (Pty) Ltd, WMB and Kwezi-V3 on behalf of the Directorate: National Water Resource Planning. DWAF Report No P WMA 14/000/00/0304

Department of Water Affairs and Forestry (DWAF), 2004. National Water Resource Strategy. Appendix D: Lower Orange River. Department of Water Affairs, Pretoria.

Department of Water Affairs and Forestry (DWAF), 2008a. National Aquatic Ecosystem Health Monitoring Programme (NAEHMP): River Health Programme (RHP) Implementation Manual. Version 2. ISBN No. 978-0-621-383343-0. Department of Water Affairs and Forestry, Pretoria, South Africa.

Department of Water Affairs and Forestry (DWAF), 2008b. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: Resource Unit. Report produced by Koekemoer Aquatic Services and Water for Africa. Authored by Louw, D. Report no: RDM/WMA8 C000/01/CON/0208.

Department of Water Affairs and Forestry (DWAF). 2009. Development of an Integrated Water Quality management Strategy for the Upper and Lower Orange Water Management Areas. Report No 2.2 (P RSA D000/00/7909/3). Department of Water Affairs, Pretoria.

Department of Water Affairs (DWA), 2010. Resource Directed Measures: Comprehensive Reserve determination study of the Integrated Vaal River System. Upper Vaal Water Management Area Technical Component: EcoClassification Report: Volume 1. Report produced by Koekemoer Aquatic Services and Rivers for Africa. Edited by Louw, D and Koekemoer, S. Report no: RDM/ WMA8 C000/01/CON/0109.

Dixit, SS, Smol, JP, Kingston, JC & Charles, DF (1992). Diatoms: Powerful indicators of environmental change. *Environmental Science and Technology* **26**: 23–33.

Gaigher, I.G., Hamman, K.C.D. and Thorne, S.C. 1980. The distribution, conservation status and factors affecting the survival of indigenous freshwater fishes in the Cape Province. *Koedoe* 23: 57-88.

Hay, C.J. 1991. The distribution of fish in the Fish River, Namibia. *Madoqua* 19: 129-141.

Heath, R. And Brown, C. 2007. Orange River Integrated Water Resources Management Plan. Environmental Considerations Pertaining to the Orange River. Orasecom Report No 005/2007. Orange Senqu River Commission.

Hocutt, C.H. and Skelton, P.H. 1983. Fishes of the Sak River, South Africa with comments on the nomenclature of the smallmouth yellowfish, *Barbus aeneus* (Burchell, 1822). J.L.B. Smith Institute of Ichthyology, Special Publication No.32, 11 pages.

Jubb, J.A. 1967. Freshwater fishes of southern Africa. A.A. Balkema, Cape Town.

Jubb, R.A. & Farquharsan, F.L. 1965. The freshwater fishes of the Orange River drainage basin. *South African Journal of Science* 61: 118-145.

Jubb, R.A. 1972. The Hendrik Verwoerd Dam and Orange River fishes. Piscator 84: 22-26.

Koekemoer S. 2010. *Water quality and diatom index correlations between epilithic and epiphytic diatom communities*. Unpublished M.Sc. thesis, North-West University, Potchefstroom Campus, Potchefstroom.

Kleynhans, C.J. 1999. The development of a fish index to assess the biological integrity of South African Rivers. *Water SA* 25(3): 265-278.

Kleynhans, C.J. 2003. National Aquatic Ecosystem Biomonitoring Programme: Report on a National Workshop on the use of Fish in Aquatic System Health Assessment. NAEBP Report Series No.16. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

Kleynhans, C.J. 2007. *Module D: Fish Response Assessment Index*. In River EcoClassification: Manual for EcoStatus Determination (version 2) Water Research Commission Report No. TT 333/08. Joint Water Research Commission and Department of Water Affairs and Forestry report, Pretoria, South Africa.

Kleynhans C.J., MacKenzie J, Louw MD. 2007a. Module F: Riparian Vegetation Response Assessment Index in River Classification: Manual for EcoStatus Determination (version 2). Joint

Water Commission and Department of Water Affairs and Forestry report. WRC Report No. TT333/08

Kleynhans, C.J., Louw, M.D & Moolman, J. 2007b. Module D (Volume 2): Reference Frequency of Occurrence of Fish Species in South Africa: Manual for EcoStatus Determination (Version 2). Joint Water Research Commission and Department of Water Affairs and Forestry Report. WRC Report No. TT330/08. Water Research Commission, Pretoria, South Africa.

Kleynhans C.J., Louw, M.D. and Graham, M. 2009. *Module G: Index of Habitat Integrity (Section 1, Technical manual)*. In River EcoClassification: Manual for EcoStatus Determination (version 2) Water Research Commission Report No. TT 333/08. Joint Water Research Commission and Department of Water Affairs and Forestry report, Pretoria, South Africa.

Kotze, P. & Koekemoer, J.H. 2010. Fish specialist component (Draft Report VI). Orange River Reserve Determination Study. Report number RFA/B/2010 drafted for Rivers for Africa. Department of Water Affairs, Pretoria.

Krammer, K and Lange-Bertalot, H (1986-1991). Bacillario-phyceae. Süßwasserflora von Mitteleuropa *2* (1-4). Spektrum Akademischer Verlag, Heidelberg. Berlin.

Lecointe, C, Coste, M and Prygiel, J (1993). "Omnidia": Software for taxonomy, calculation of diatom indices and inventories management. Hydrobiologia 269/270: 509-513.

Leira, M and Sabater, S (2005). Diatom assemblages distribution in Catalan rivers, NE Spain, in relation to chemical and physiographical factors. Water Research **39**: 73-82

Le Roux A. 2005. Namaqualand. South African Wild Flower Guide 1. Third Revision. National Botanical Society of South Africa, Cape Town.

Low B.A., Rebello A.G. (eds) 1998. Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria

Mucina L. & Rutherford M.C. (eds) 2005. VEGMAP. Wall Map South African National Biodiversity Institute, Pretoria

Mucina L. & Rutherford M.C. (eds) 2006. Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia 19*. South African National Biodiversity Institute, Pretoria

Mulder, P.F.S. 1973. Aspects on the ecology of *Barbus kimberleyensis* and *Barbus holubi* in the Vaal River. *Zoologica Africana* 8(1): 1-14.

Næsje, T.F., Hay, C.J., Nickanor, N., Koekemoer, J., Strand, R. and Thorstad, E.B. 2007. Fish populations, gill net catches and gill net selectivity in the lower Orange River, Namibia, from 1995-2001. NINA Report 231: 81 pp.

Okeyo (Unknown) : Biodiversity and distribution of freshwater fish of Namibia. Available at : ftp://ftp.cordis.europa.eu/pub/inco2/docs/19_dookeyo.pdf. Accessed on 22 November 2010

ORASECOM (Orange Senqu River Commission). 2008. Preliminary Transboundary Diagnostic Analysis. Main Report. ORASECOM.

ORASECOM. 2007. Orange River Integrated Water Resources Management Plan. Set of 12 reports. Orange Senqu River Commission.

Palmer, R.W. 1996. Invertebrates of the Orange River with emphasis on conservation and management. *South African Journal of Aquatic Science* 22(1/2): 3-51.

Prygiel J and Coste M 2000*. Guide méthodologique pour la mise en oeuvre de l'Indice Biologique Diatomées*. NF T 90-354. Agence de l'eau Artois Picardie, Douai.

Prygiel J, Carpentier P, Almeida S, Coste M, Druart JC, Ector L, Guillard D, Honoré MA, Iserentant R, Ledeganck P, Lalanne-Cassou C, Lesniak C, Mercier I, Moncaut P, Nazart M, Nouchet N, Peres F, Peeters V, Rimet F, Rumeau A, Sabater S, Straub F, Torrisi M, Tudesque L, Van der Vijver B, Vidal H, Vizinet J and Zydek N (2002) Determination of the biological diatom index (IBD NF T 90-354): results of an inter-comparison exercise. *Journal of Applied Phycology* **14**: 27-39.

Seaman, M.T. and van As, J.G. 1998. The environmental status of the Orange River Mouth as reflected by the fish community. Water Research Commission Report Number 505/1/98. 73 pp.

Schoeman, FR (1973). A systematical and ecological study of the diatom flora of Lesotho with special reference to water quality. V&R Printers, Pretoria, South Africa.

Skelton, P.H. 1986. Fish of the Orange-Vaal system. In: Davies, B.R. and Walker, K.F. (eds). The ecology of river systems.Dr W. Junk Publishers, Dordrecht: 143-161.

Skelton, P.H. 2001. A complete guide to the freshwater fishes of southern Africa. Southern Book Publishers, Halfway House.

Skelton, P.H. and Cambray, J.A. 1981. The freshwater fishes of the middle and lower Orange River. *Koedoe* 24: 51-66.

Taylor, J.C., De la Rey, P.A. and Van Rensburg, L. 2005. Recommendations for the collection, preparation and enumeration of diatoms from riverine habitats for water quality monitoring in South Africa. African Journal of Aquatic Science **30** (1): 65-75.

Taylor, J.C., Harding, W.R. and Archibald, C.G.M. 2007. A Methods Manual for the Collection, Preparation and Analysis of Diatom Samples. Version 1.0. WRC Report No. 281/07. Water Research Commission, Pretoria.

Thirion, C. 2007. *Module E: Macrinvertebrate Response Assessement Index.* In River EcoClassification: Manual for Ecostatus Determination (version 2). Water Research Commission Report No. TT 333/08. Joint Water Research Commission and Department of Water Affairs and Forestry report, Pretoria, South Africa.

Tilman, D, Kilham, SS, & Kilham, P (1982). Phytoplankton community ecology: The role of limiting nutrients. *Annual Review of Ecology and Systematics* **13**: 349–372.

Van Wyk B. & Van Wyk P. 2009. Field Guide to trees of Southern Africa. 12th Impression. Struik Nature Publishers, Cape Town.

Van Zyl, B.J., Hay, C.J. and Steyn, G.J. 1995. Some aspects of the reproduction biology of *Labeo capensis* (Smith, 1941) (Pisces, Cyprinidae) in relation to exploitation and extreme environmental conditions in Hardap Dam, Namibia. South African Journal of Aquatic Science 21(1/2): 88-98.

Water for Africa (2010a). Work package 5: Assessment of Environmental Flow Requirements as part of Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan. Deliverable 10: Resource Unit Report. Compiled by MD Louw, produced for WRP.

Water for Africa (2010b). Work package 5: Assessment of Environmental Flow Requirements as part of Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan. Deliverable 12: EFR Report. Editors: Louw MD and S Koekemoer. Produced for WRP.