Orange-Senqu River Basin

Orange-Senqu River Commission Secretariat
Governments of Botswana, Lesotho, Namibia and South Africa

UNDP-GEF
Orange-Senqu Strategic Action Programme
(Atlas Project ID 71598)

River EFR assessment, Volume 2: Lower Orange River EFR, supporting information

Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth

Technical Report 30
Rev 4, 30 October 2013

UNDP-GEF
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River EFR assessment, Volume 2: Lower Orange River EFR, supporting information

Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth

This report was compiled by Rivers for Africa, e-Flows Consulting (PTY) LTD (iwre@icon.co.za), Pretoria, South Africa with assistance from Ministry of Environment and Tourism, Directorate of Parks and Wildlife Management and South African National Parks during surveys and hydrological observed/real time data obtained from Ministry of Agriculture, Water and Forestry, Department of Water Affairs and Forestry, Namibia.

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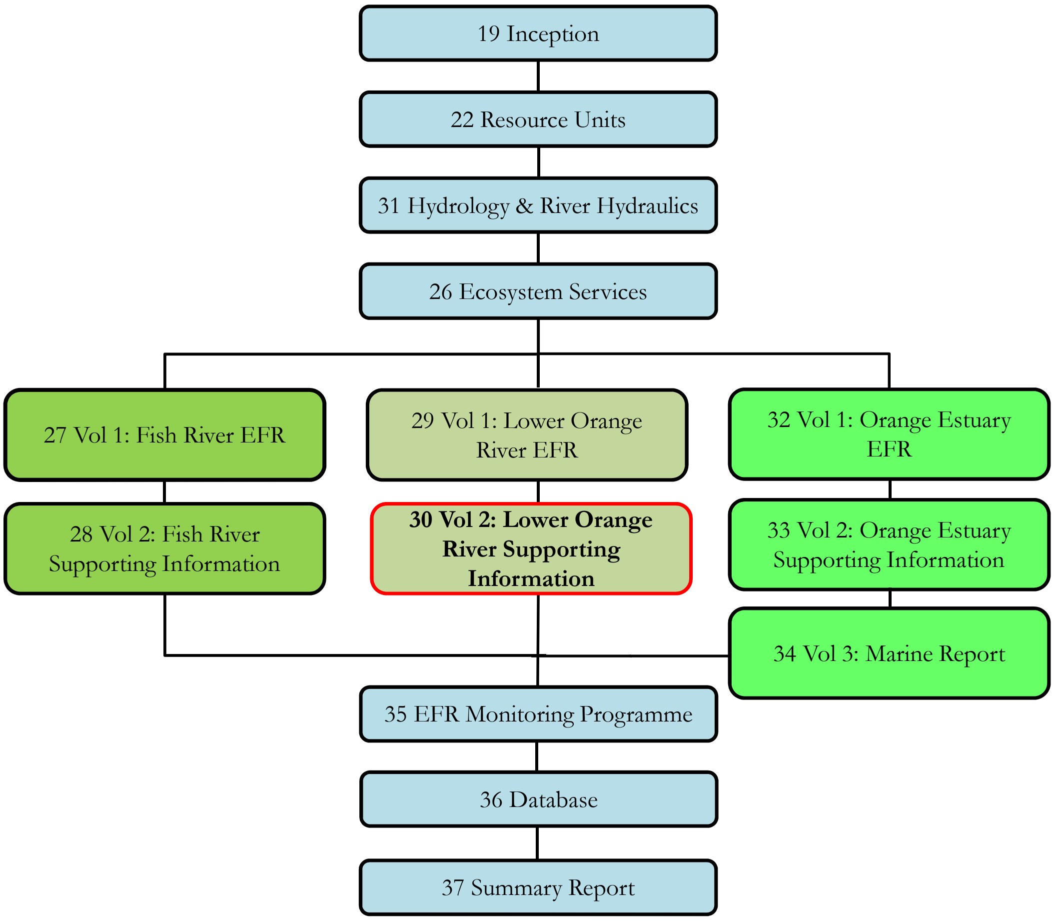
Report list

A list of the Technical Reports that form of this study is provided below. A diagram illustrating the linkages between the reports is also provided.

Technical Report No	Report
19	Inception Report, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
22	Delineation of the Study Area – Resource Unit Report, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
26	Consequences of Scenarios on Ecosystem Services, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
27	River EFR assessment, Volume 1: Determination of Fish River EFR Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
28	River EFR assessment, Volume 2: Fish River EFR, supporting information Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
29	River EFR assessment, Volume 1: Determination of the lower Orange River EFR Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
30	**River EFR assessment, Volume 2: Lower Orange River EFR, supporting information** **Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth**
31	River and Estuary EFR assessment, Hydrology and River Hydraulics Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
32	Estuary and Marine EFR assessment, Volume 1: Determination of Orange Estuary EFR Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
33	Estuary and Marine EFR assessment, Volume 2: Orange Estuary EFR: Supporting Information Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
34	Estuary and Marine EFR assessment, Volume 3: Assessment of the Role of Freshwater Inflows in the Coastal Marine Ecosystem Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
35	EFR monitoring programme, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
36	Database, Research project on environmental flow requirements of the Fish River and the Orange-

Technical Report No	Report
	Senqu River Mouth
37	Summary Report, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth

Bold indicates current report.



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Authors of this report

Authors	Association
Dr Andrew Deacon	Private
Shael Koekemoer	Koekemoer Aquatic Services
Dr Piet Kotze	Clean Stream
Delana Louw	Rivers for Africa
James Mackenzie	Mackenzie Ecological and Development Services
Dr Rob Palmer	Nepid Consultants
Mark Rountree	Fluvial Environmental Consultants
Dr Patsy Scherman	Scherman Colloty & Associates

Maps
Dr Piotr Wolski

Internal Review
Dr Bernt Rydgren
Dr Hugo Bezuidenhout
Mr Wayne Hendley
Ms Sue Mathews (Executive summary)

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Abbreviations

ASPT	*Average score per taxon*
CEV	*Chronic effects value*
DO	*Dissolved oxygen*
DWA	*Department of Water Affairs*
DWA: RQS	*Department of Water Affairs Resource Quality Services*
EC	*Ecological category*
EFR	*Environmental flow requirement*
FRAI	*Fish Response Assessment Index*
FROC	*Frequency of occurrence*
GAI	*Geomorphological Driver Assessment Index*
IHI	*Index of Habitat Integrity*
IWRM	*Integrated water resources management*
IUCN	*International Union for Conservation of Nature*
IWRM	*Integrated water resources management*
MCB	*Macro channel bank*
MIRAI	*Macro Invertebrate Response Assessment Index*
MRU	*Management resource unit*
NASS2	*Namibian Scoring System version 2*
NEMBA	*National Environmental Management: Biodiversity Act*
ORASECOM	*Orange-Senqu River Commission*
ORRS	*Orange River Replanning Study*
PAI	*Physico-chemical Driver Assessment Index*
PES	*Present ecological state*
RC	*Reference condition*
SANBI	*South African National Biodiversity Institute*
SASS5	*South African Scoring System version 5*
SPI	*Specific Pollution sensitivity Index*
TDI	*Trophic Diatom Index*
TIN	*Total inorganic nitrogen*
TWQR	*Target water quality range*
VEGRAI	*Vegetation Response Assessment Index*

Fish species abbreviations

ASCL	*Austroglanis sclateri*
BAEN	*Labeobarbus aeneus*
BHOS	*Barbus hospes*
BKIM	*Labeobarbus kimberleyensis*
BKIM X BAEN (B. cf. KIM)	*Labeobarbus hybrid*
BPAU	*Barbus paludinosus*
BTRI	*Barbus trimaculatus*
CCAR	*Cyprinus carpio*
CGAR	*Clarias gariepinus*
LCAP	*Labeo capensis*
LCAP X LUMB	*Labeo hybrid*
LUMB	*Labeo umbratus*
MBRE	*Mesobola brevianalis*
MSAL	*Micropterus salmoides*
OMOS	*Oreochromis mossambicus*
PPHI	*Pseudocrenilabrus philander*
TSPA	*Tilapia sparrmanii*

Velocity Depth Classes: Fish

FD	*Fast deep fish habitat*
FI	*Fast intermediate fish habitat*
FS	*Fast shallow fish habitat*
SD	*Slow deep fish habitat*
SS	*Slow shallow fish habitat*

1. Introduction

1.1 Background

The Orange-Senqu River riparian States (Botswana, Lesotho, Namibia and South Africa) are committed to jointly addressing threats to the shared water resources of the Basin. This is reflected in bilateral and basin-wide agreements between the riparian states and led to the formation of the Orange-Senqu River Commission (ORASECOM) in 2000. The Orange-Senqu Strategic Action Programme supports ORASECOM in developing a basin-wide plan for the management and development of water resources, based on integrated water resources management (IWRM) principles (ORASECOM, 2011a).

The water resources of the Orange-Senqu River are heavily utilised and the system is highly regulated with 23 major dams within its Basin. It is also connected to other river systems for water import and export via six inter-basin water transfer schemes (Technical Report 22).

Environmental flow requirements (EFR) of the ephemeral but nevertheless significant Fish River, and the Orange River, from its confluence with the Fish River downstream to the Orange River mouth were not covered in any detail by the completed GIZ study, during 2009-2010 (Louw and Koekemoer (Eds), 2010). This area is to be the subject of this Research Project (ORASECOM, 2011a).

1.2 Objectives of the study

The objectives of this study for the lower Orange River were to:

- determine the present ecological state (PES) and describe alternative ecological states if relevant;
- set the EFR;
- address scenarios in terms of the existing and new dams in the lower Orange River (also providing input to release specifications).

1.3 Study area

The study area (Figure 1) includes the following areas (Technical Report 22):

- Orange-Senqu River from the Fish River confluence downstream to the Orange-Senqu River estuary including the estuary and the immediate marine environment; and the
- Fish River in Namibia.

1.4 Delineation and study sites

Information per EFR site in the study area is shown in Table 1 below, and is taken from Technical Report 22.

Table 1. Details of EFR sites

EFR site	***River***	***Management resource unit***	***Land cover***
EFR Fish 1	Fish	MRU[1] Fish A: Hardap to Neckartal Dam	Irrigation (1%) and livestock farming (99%)
EFR Fish 2	Fish	MRU Fish B.1: Neckartal Dam to Löwen/Fish River confluence	Nature reserves (90%) and other (10%) (e.g. Seeheim: livestock farming)
EFR Fish Ai-Ais	Fish	Löwen/Fish River confluence to Orange River confluence	
EFR O5	Orange	MRU Orange G: Fish River confluence to start of estuary	National Parks, mining, irrigation

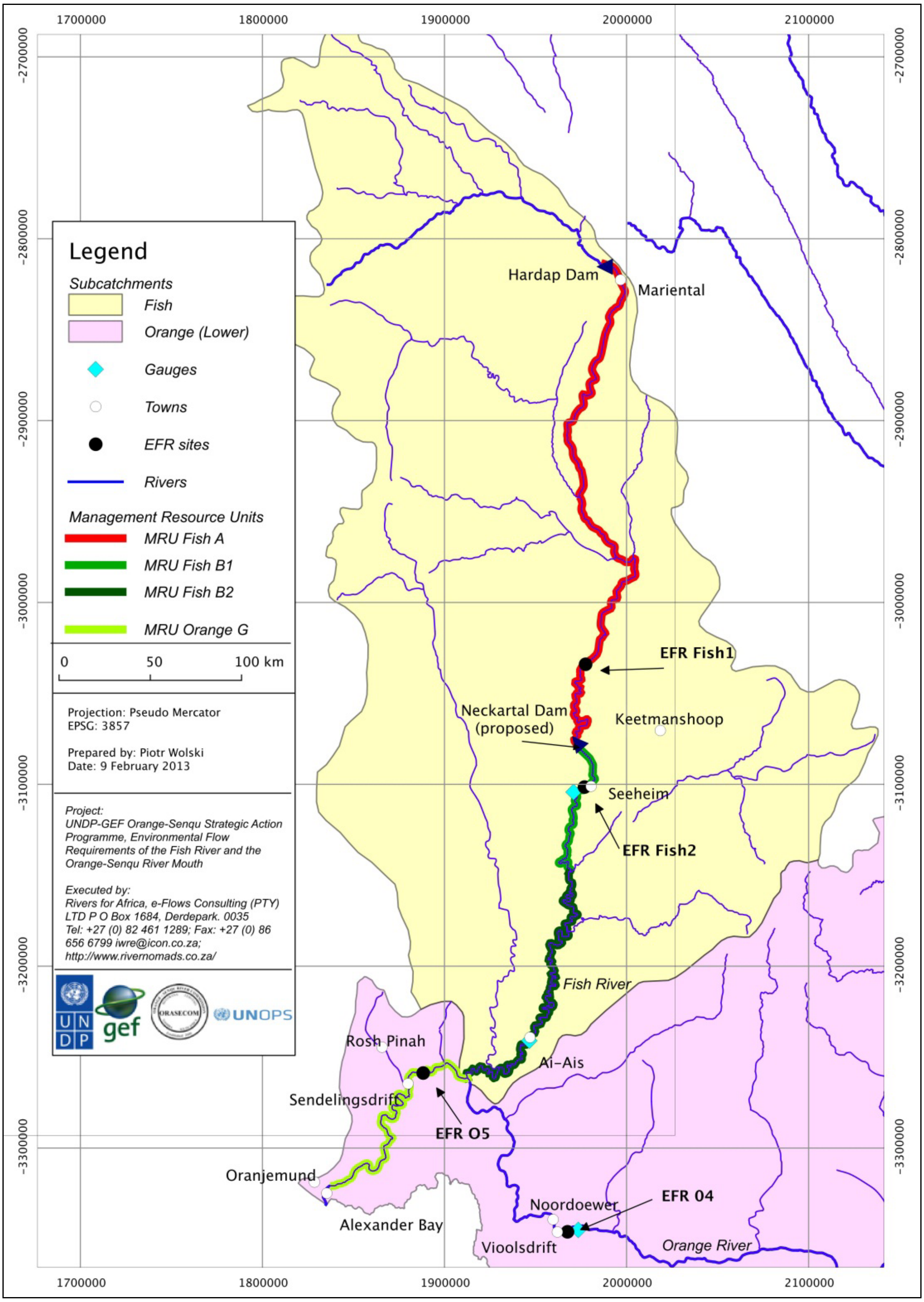

Figure 1. Study area

1.5 Report structure

The EcoClassification and EFR determination of the Fish and Orange rivers are documented in five reports:

- Technical Report 27: River EFR assessment, Volume 1: Determination of Fish River EFR Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth.
- Technical Report 28: River EFR assessment, Volume 2: Fish River EFR, supporting information Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth.
- Technical Report 29: River EFR assessment, Volume 1: Determination of the lower Orange River EFR Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth.
- **Technical Report 30: River EFR assessment, Volume 2: Lower Orange River EFR, supporting information Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth.**
- Technical Report 31: River and Estuary EFR assessment, Hydrology and River Hydraulics Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth.

Technical Report 30 is a collection of supplementary technical information which includes data collected from a site visit undertaken during 13-22 June 2012 and literature surveys. This volume provides supporting information and background to Technical Report 29. Each specialist contribution forms a chapter of this volume. This document should not be seen as a stand-alone volume but should be read in conjunction with Technical Report 29. All component assessment indices and raw data are provided on the ORASECOM website (www.orasecom.org).

The report consists of the following chapters:

Chapter 1: Preface
This chapter provides an overview of the study area and objectives of the study.

The individual specialist reports are provided as the following chapters:

Chapter 2: Water quality

Chapter 3: Diatoms

Chapter 4: Geomorphology

Chapter 5: Riparian vegetation

Chapter 6: Riverine fauna

Chapter 7: Macro-invertebrates

Chapter 8: Fish

Chapter 9: Habitat integrity of the Fish River

Chapter 10: References

Appendix A: Species Lists
This Appendix lists the riparian vegetation species observed at the EFR site of the Orange River.

Appendix B: Riverine fauna habitat plan views
The plan views linked to habitats showing the differences in height above water level experienced during the site visit are provided.

Appendix C: Fish information used during the ecological classification process
A summary of available data and survey results are provided. The preference of fish for different velocity-depth categories and cover features and different tolerance levels to changes in their environment is provided.

2. Water quality

This chapter addresses the data used and assessment of the PES for the water quality of the Orange River downstream of the Fish River confluence.

2.1 Methods and approach

The methods and approach described in DWAF (2008) and not provided in detail in this document. The following parameters were evaluated:

- pH: 5th and 95th percentiles.
- Electrical Conductivity, ions, metals: 95th percentiles.
- Nutrients, i.e. Total Inorganic Nitrogen (TIN) and ortho-phosphate: 50th percentile.
- Chlorophyll-a (phytoplankton): Average or mean of values.
- Diatoms: average or mean of values.
- Turbidity, dissolved oxygen (DO), temperature: narrative descriptions as no data are available.

Water quality data were utilised in the following way: Nutrients, pH, chlorophyll-a, turbidity, DO, temperature and electrical conductivity data were compared to benchmark values in DWAF (2008), while all ionic data (i.e. macro-ions and salt ions) were compared to benchmark tables in DWAF (2008) or the target water quality range (TWQR) guidelines of the South African aquatic ecosystem guidelines (DWAF, 1996a). Diatom data were utilised as provided by the diatomologist for the study.

2.2 Reference conditions

The most critical part of a water quality assessment is setting reference condition (RC), which represents the natural state. The change or deviation from RC defines the water quality present state. As water quality data for the RC are often not available, a range of options have to be available to set the natural state for water quality, e.g. using data from another river in the same Level II EcoRegion; using data from the closest suitable monitoring point, generating a RC from available data, using RC data as indicated in DWAF (2008) for an A category river (which indicates an unimpacted system) or generating a RC from available literature and specialist opinion.

2.3 Available information and confidence

Figure 2 shows the position of the South African Department Water Affairs (DWA) gauging weirs and water quality monitoring points. Site EFR O4 was assessed for the 2010 ORASECOM Study of the Orange River. Note the following points regarding water quality, cited by Scherman (2010) and taken from a draft document on monitoring resource quality in the Orange-Senqu River Basin (ORASECOM, November 2009).

- Water quality downstream of Onseepkans remains good although salinity increases are observed towards the mouth of the Orange River due to factors such as increasing aridity, evaporation and tidal influences.
- The flushing of salts that are built up in the soils may occur during high flows.
- Return flows from the irrigation areas contribute salinity and nutrients to the Orange River (ORASECOM, 2007).
- It was noted with concern during the Orange River Replanning Study (ORRS) (DWAF, 1998) that there was a decrease in salt load down the river at the time, which indicates that salt was being retained in the system. There was also a marked annual cyclicity in the salt concentration of the water downstream of Vioolsdrift, with variations between 400 mg/ℓ and 1 500 mg/ℓ. Under these circumstances only salt-tolerant crops such as dates and wheat could be grown.
- It was assumed that any increases in irrigation along the lower reaches of the Orange River would lead to higher return flows which would further increase the salinity of the water in the river. This effect will be most felt downstream of Vioolsdrift, where the last significant volume of water is abstracted and return flows will form the bulk of the flow in the river during dry periods (DWAF, 1998).
- The concentration of some metals, i.e. Al, Cd, Cu and Pb, were occasionally unacceptably high and potentially harmful for human health and for the aquatic environment. The reason for the high metal concentrations at Upington, Neusberg weir, Pella and Vioolsdrift were unclear and should be investigated further. Mining activities in the area could be a potential source of some of the metals observed (Golder Associates, 2009; ORASECOM, 2009).
- Localised eutrophication and microbial pollution is known along the Caledon River, along the Orange River downstream of Lesotho and downstream of the Upington irrigation area to Namibia. Although these areas are all a distance away from the study area, they are indicators of pollution in the system which would move downstream. Note that there is insufficient information to determine the transboundary extent of this pollution.

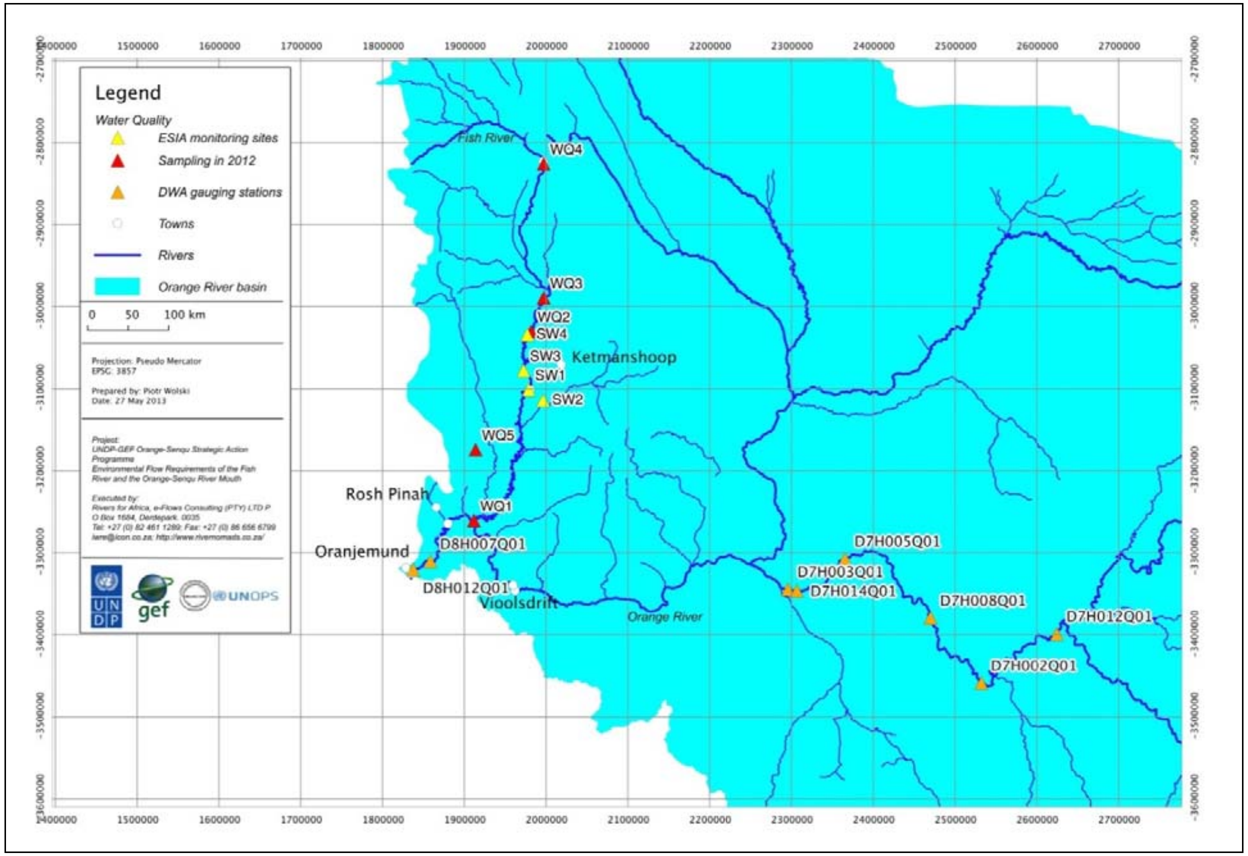

Figure 2. Water quality data available from DWA gauging weirs for the Orange River area

Table 2. Available data for the lower Orange River area

DWA gauge	Number of samples	First sample date	Last sample date
D8H007Q01 Orange River at Korridor Brand Karos	414	1971/08/08	2002/04/16
D8H012Q01 Orange River at Alexander Bay @ Sir Ernest Oppenheimer Bridge	286	1995/05/16	2003/05/19

2.4 Data assessment

Table 3 shows the water quality present state assessment for EFR O5. Reference conditions were derived from Orange River at Korridor Brand Kaross, D8H007Q01 (1980; n=35). The water quality site used for this assessment is Orange River at Oppenheimer Bridge, Alexander Bay, D8H012Q01, (1995 – 2003; n=263) and diatom data. Diatoms were collected at four sites within the reach between 2005 and 2012, with an overall assessment of a C to C/D category. The Physico-chemical Driver Assessment Index (PAI) results are provided in Table 4. The confidence is low - moderate confidence as the data record for the present state is not recent and gaps exist for data such as metal ions, pesticides, herbicides. RC data is also poor.

Table 3. Water quality present state assessment for EFR O5

Water quality constituents	RC value	PES value	Category/Comment
Inorganic salt ions (mg/ℓ)			
Ca	28.06	44.07	PES data show significant elevations as compared to the natural state.
Cl	27.1	73.05	PES data show significant elevations as compared to the natural state.
K	1.92	5.62	PES data show significant elevations as compared to the natural state.
Mg	12.36	22.08	PES data show significant elevations as compared to the natural state.
Na	32.34	76.97	PES data show significant elevations as compared to the natural state.
SO_4	33.16	84.3	PES data show significant elevations as compared to the natural state.
Nutrients (mg/ℓ)			
SRP	0.006	0.026	C/D
TIN	0.06	0.076	A
Physical Variables			
pH (5^{th} + 95^{th} %ile)	6.77 and 7.53	8.10 and 8.60	A/B
Temperature	No data		Impacts expected due to the extreme reductions of flow for large parts of the year, although now more similar to natural.
Dissolved oxygen	No data		

Water quality constituents	***RC value***	***PES value***	***Category/Comment***
Turbidity (NTU)	No data	10.24 (avg; n=9)[1]	No RC or DWA PES data. Turbidity from system trapped in dams. B category (qualitative assessment). Also sediment from the upstream Fish River.
Electrical Conductivity (mS/m)	38.03[2]	72.96	B
Response variables			
Chl a: phytoplankton (µg/ℓ)	No data	Avg: 25.2 (n=9)[1]	D
Macro-invertebrate score (MIRAI)[3]		78%	B/C
Fish score (FRAI)[4]		79.90%	B/C
Diatoms	No data	SPI[5]: 11.4	C/D
Toxics			
Fluoride (mg/ℓ)	0.38	0.5	A
Aluminum (mg/ℓ)	0.02[6]	0.042 (n=9)[1]	A
Iron (mg/ℓ)	No data	0.035 (n=9)[1]	No guideline and insufficient data
Ammonia (mg/ℓ)	0.001	0.01	A
Copper (mg/ℓ)	0.003[4]	0.013	E
Zinc (mg/ℓ)	0.0002: TWQR[7] 0.0036: CEV[7]	0.0056	Both SA ecosystem guidelines exceeded
Other	No data	No data	Impacts expected due to farming activities, large abstractions and mining.
Overall site classification (PAI model)			**C (74.2%)**

- no data
1 Data obtained from Koekemoer (2010).
2 Boundary value for the A category recalibrated
3 Macroinvertebrate Response Assessment Index
4 Fish Response Assessment Index
5 Benchmark value, as no data
6 Specific Pollution Index score
7: TWQR and Chronic effects value (CEV) obtained from DWAF (1996a).

Table 4. PAI table for EFR O5

Metric	***Rating***	***Confidence***
pH	0.5	3
Salts	1.5	3
Nutrients	1.5	4
Water temperature	1	2
Water Clarity	1	3.5
Oxygen	1	2
Toxics	2	2
PC modification rating	1.29	
PC Category (%)	**C (74.2%)**	

2.5 Conclusions

The main water quality issues in this section are elevated nutrient loads, elevations in salts and some elevated metals. There have also been reports of health incidents (blisters and skin rashes after rafting in the Orange River) and fish kills in the Richtersveld (De Hoop camp and Grasdrif respectively) during April 2008, with an additional fish kill incident in May 2008 (confirmed by Bezuidenhout, SANParks, November 2010). Causes are unknown although fish kills might be related to seasonal temperature changes and human skin conditions due to toxic cyanobacteria or *Schistosome cercarial dermatitis* (Palmer, Nepid Consultants, pers. comm., November 2010). The latter is also known as swimmer's itch, duck itch or cercarial dermatitis.

3. Diatoms

3.1 Background

Algal-based bio-assessments in streams have been extensively researched worldwide and applied in regular riverine- and lake-monitoring programmes with great success. Diatoms are commonly employed in monitoring efforts as sensitive biological indicators to determine the anthropogenic impact on aquatic ecosystems, and have for a long time been used in bio-assessments (Kasperovičienė and Vaikutienė, 2007). As benthic diatom assemblages are sessile they are exposed to water quality at a site over a period antecedent to sampling. They therefore indicate recent as well as current water quality (Philibert et al., 2006).

The aim of the diatom sampling and analysis within the context of this study was to provide biological water quality information for conditions on the day of biological-component sampling regarding the aquatic health and functioning of the aquatic system, and providing additional input to the physico-chemical component of the study as a response variable. The overall objective of this report was to assess the impacts of anthropogenic activities on the Present Ecological State of the receiving aquatic ecosystem.

3.2 Terminology

Terminology used in this chapter is outlined in Taylor et al. (2007a) and summarised below.

Variable	***Description***
Trophy	
Dystrophic	Rich in organic matter, usually in the form of suspended plant colloids, but of a low nutrient content.
Oligotrophic	Low levels or primary productivity, containing low levels of mineral nutrients required by plants.
Mesotrophic	Intermediate levels of primary productivity, with intermediate levels of mineral nutrients required by plants.
Eutrophic	High primary productivity, rich in mineral nutrients required by plants.
Hypereutrophic	Very high primary productivity, constantly elevated supply of mineral nutrients required by plants.
Mineral content	
Very electrolyte poor	< 50 µS/cm
Electrolyte-poor (low electrolyte content)	50 - 100 µS/cm
Moderate electrolyte content	100 - 500 µS/cm
Electrolyte-rich (high electrolyte content)	> 500 µS/cm

Variable	*Description*
Brackish (very high electrolyte content)	> 1,000 µS/cm
Saline	6,000 µS/cm
Pollution (Saprobity)	
Unpolluted to slightly polluted	BOD <2, O_2 deficit <15% (oligosaprobic)
Moderately polluted	BOD <4, O_2 deficit <30% (β-mesosaprobic)
Critical level of pollution	BOD <7 (10), O_2 deficit <50% (β-α-mesosaprobic)
Strongly polluted	BOD <13, O_2 deficit <75% (α-mesosaprobic)
Very heavily polluted	BOD <22, O_2 deficit <90% (α-meso-polysaprobic)
Extremely polluted	BOD >22, O_2 deficit >90% (polysaprobic)

3.3 Available data

Diatom samples were collected at the EFR site as part of this study. Two sets of historic diatom data were available for the period 2008-2010:

- Diatom samples collected during April–June 2008 and during August-September 2009 as part of a water quality monitoring and status quo assessment study of the Orange-Senqu River and associated tributaries (ORASECOM, 2009).
- Diatom samples collected as part of the Baseline Monitoring of Aquatic Ecosystem Health in the Orange-Senqu River Basin study undertaken during 2010 (ORASECOM, 2011b and c).

The confidence in data availability is provided in Table 5. Historic and present sampling locations are provided in Figure 3.

Table 5. Confidence in diatom data availability

Site	*Data availability*	*Confidence*
EFR O5	Site-specific diatom data were available (2008–2009) as well as data from sample collected during EFR site visit. Diatom samples were collected during 2005, 2008–2010 across the reach, along with measured in situ water quality measurements.	3

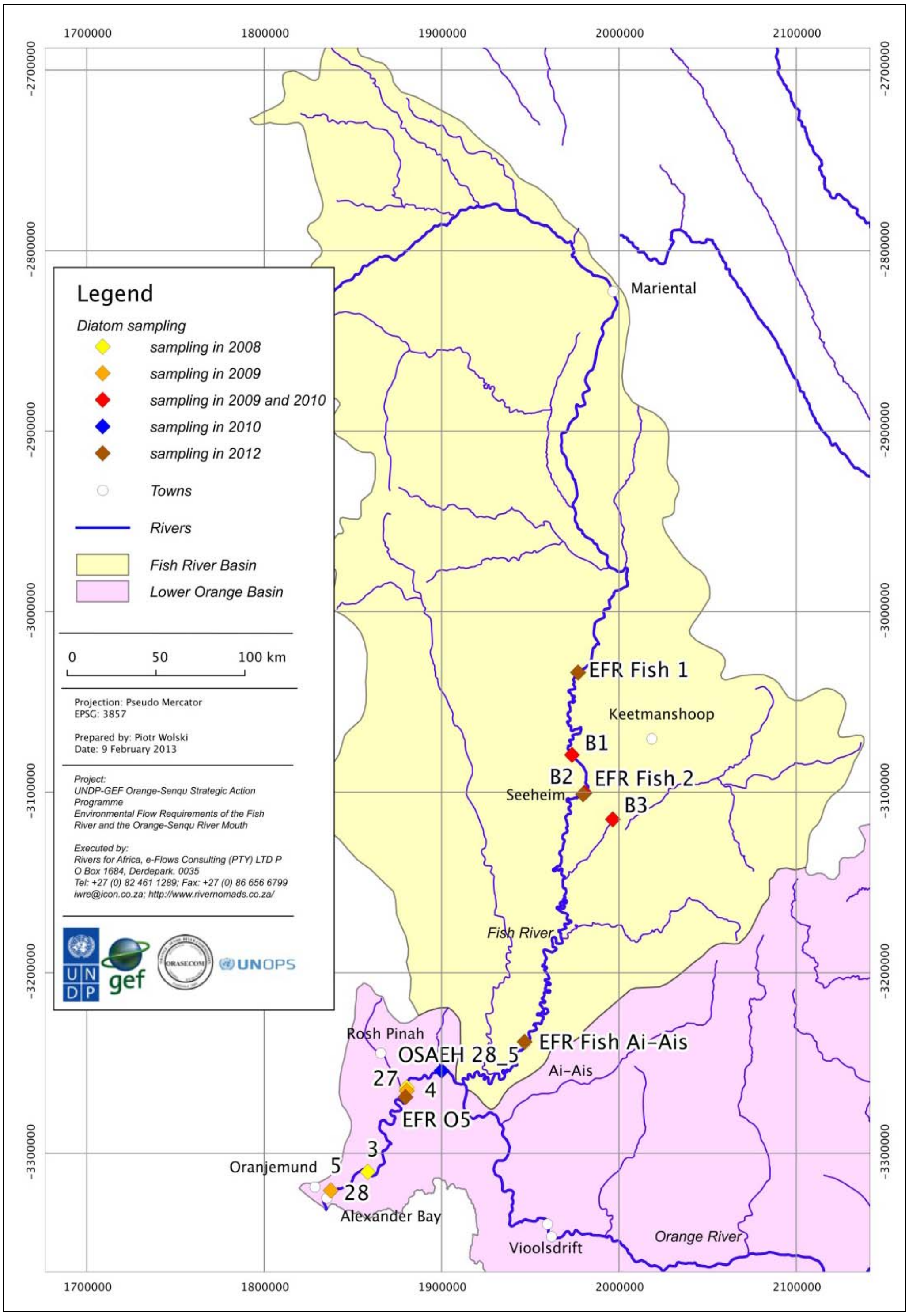

Figure 3. Location of diatom sampling sites, 2008-2012 in the Fish and Orange River

3.4 Methods

3.4.1 Sampling

Sampling methods were followed as outlined in Taylor et al. (2007a) which were designed and refined as part of the Diatom Assessment Protocol, a Water Research Commission initiative.

3.4.2 Slide preparation and diatom enumeration

Preparation of diatom slide followed the Hot HCl and $KMnO_4$ method as outlined in Taylor et al. (2007a). A Nikon Eclipse E100 microscope with phase contrast optics (1000x) was used to identify diatom valves on slides. A count of 400 valves per sample or more was enumerated for all the sites based on the findings of Schoeman (1973) and Battarbee (1986) in order to produce semi-quantitative data from which ecological conclusions can be drawn (Taylor et al., 2007a). Nomenclature followed Krammer and Lange-Bertalot (1986-91) and diatom index values were calculated with the database programme OMNIDIA (Lecointe et al., 1993).

3.4.3 Diatom-based water quality indices

The specific water quality tolerances of diatoms have been resolved into different diatom-based water quality indices, used around the world. Most indices are based on a weighted average equation (Zelinka and Marvan, 1961). In general, each diatom species used in the calculation of the index is assigned two values; the first value (s value) reflects the tolerance or affinity of the particular diatom species to a certain water quality (good or bad) while the second value (v value) indicates how strong (or weak) the relationship is (Taylor, 2004). These values are then weighted by the abundance of the particular diatom species in the sample (Lavoie et al., 2006; Taylor, 2004; Besse, 2007). The main difference between indices is in the indicator sets (number of indicators and list of taxa) used in calculations (Eloranta and Soininen, 2002).

These indices form the foundation for developing computer software to estimate biological water quality. OMNIDIA (Lecointe et al., 1993) is one such software package; it has been approved by the European Union and is used with increasing frequency in Europe and has been used for this study. The program is a taxonomic and ecological database of 7500 diatom species, and it contains indicator values and degrees of sensitivity for given species. It permits the user to perform rapid calculations of indices of general pollution, saprobity and trophic state, indices of species diversity, as well as of ecological systems (Szczepocka, 2007).

3.4.4 Data analysis

Diatom-based water quality score

The European numerical diatom index, the Specific Pollution sensitivity Index (SPI) was used to interpret results. De la Rey et al. (2004) concluded that the SPI reflects certain elements of water quality with a high degree of accuracy due to the broad species base of the SPI. The interpretation of the SPI scores was adjusted during 2011 (Taylor and Koekemoer, in press) and the new adjusted class limits are provided in Table 6. The new adjustments will affect diatom-derived Ecological Categories from previous studies and therefore all previous results have been adjusted accordingly.

Table 6. Adjusted class limit boundaries for the SPI index applied in this study

Interpretation of index scores		
Ecological category	***Class***	***Index score (SPI score)***
A	High quality	18 - 20
A/B	High quality	17 - 18
B	Good quality	15 - 17
B/C	Good quality	14 - 15
C	Moderate quality	12 - 14
C/D	Moderate quality	10 - 12
D	Poor quality	8 - 10
D/E	Poort quality	6 - 8
E	Bad quality	5 - 6
E/F	Bad quality	4 - 5
F	Bad quality	<4

Diatom based ecological classification

Ecological characterisation of the samples was based on Van Dam et al. (1994). This work includes the preferences of 948 freshwater and brackish water diatom species in terms of pH, nitrogen, oxygen, salinity, humidity, saprobity and trophic state as provided by OMNIDIA (Le Cointe et al., 1993). The results from the Trophic Diatom Index (TDI) (Kelly and Whitton, 1995) were also taken into account as this index provides the percentage pollution tolerant diatom valves (PTVs) in a sample and was developed for monitoring sewage outfall (orthophosphate-phosphorus concentrations), and not general stream quality. The presence of more than 20% PTVs shows significant organic impact.

3.5 Results

The diatom results are provided per MRU for the Orange River main stem below the Fish River confluence and the Fish River. All historic diatom data are summarised in this report as the diatom results are discussed in detail in the respective reports (ORASECOM, 2011b,c; Nepid Consultants, 2010; Koekemoer, 2010). Figure 3 illustrates the sites where diatom samples were collected in the study area.

3.5.1 MRU Orange G: Fish River confluence to start of Estuary

Diatoms were collected at four sites within this reach during the period 2008–2012. The diatom results for 2008–2012 are discussed in the following sections.

OSAEH 28_5

A diatom sample was collected approximately 23 km upstream of Sendelingsdrift (ORASECOM, 2011b;c). The SPI score and ecological classification according to Van Dam et al. (1994) for the sample is provided in Table 7.

Table 7. Summary of diatom results at OSAEH 28_5

Variable	*Description*
pH	Alkaline
Trophy	Meso-eutrophic
Salinity	Fresh brackish
Oxygen	Continuously high
Nitrogen metabolism	Very small
SPI	14.4
EC	B/C

According to ORASECOM (2011b,c) the reach was determined to be in a C EC, with nutrient levels that were elevated at times and slight levels of pollution were present.

The dominant species included *Encyonopsis minuta* and *Encyonopsis microcephala* which are cosmopolitan and found in calcareous waters with moderate electrolyte content and requires an oxygen-rich environment (Taylor et al., 2007b). The high abundance of *Thalassiosira pseudonana* indicated that salinity levels may have been elevated as this species is a halophilic planktonic species (Taylor et al., 2007b). Organic pollution levels were very low with PTVs making up 1.3% of the total count and these levels may account for the low pollution levels at the site.

Sample 4 and 27: Sendelingsdrift

This site was sampled during June 2008 (Sample 4) and August 2009 (Sample 27) and is situated approximately 2 km upstream of Sendelingsdrift. This site was proposed as one of eleven Transboundary Water Quality Monitoring Stations (Station 10) and as the first monitoring site in the Orange River below the confluence of the Fish River, this site was deemed important to detect water quality changes due to the Fish River (ORASECOM, 2009). The SPI scores and ecological classification according to Van Dam et al. (1994) for the two samples are provided in Table 8.

Table 8. Summary of diatom results at Site 4 and 27

Variable	*Description*	
	Site 4	*Site 27*
pH	Alkaline	Alkaline
Trophy	Hyper-eutrophic	Eutrophic
Salinity	Fresh brackish	Fresh brackish
Oxygen	Moderate	Continuously high

Variable	*Description*	
	Site 4	*Site 27*
Nitrogen metabolism	Elevated	Continuously high
SPI	10.1	10.1
EC	C/D	C/D

The following information is an extract from Koekemoer (2010):

During June 2008 the sample was dominated by *Fragilaria sundayensis*, *Nitzschia palea*, *Discostella pseudostelligera* and *Stephanodiscus minutulus*. *Nitzschia palea* occurs in eutrophic and heavily to extremely polluted waters while *S. minutulus* is found in strongly polluted waters with high electrolyte content (Taylor et al., 2007b). Based on the TDI (Kelly and Whitton, 1995), organic pollution levels were elevated with PTVs making up 18.2% of the total count. Nutrients levels seemed elevated but were not problematic. During August 2009 the sample was dominated by *Fragilaria geocollegarum*, *E. microcephala*, *Sellaphora* species, *Nitzschia frustulum* and *Achnanthidium saprophila*. Organic pollution levels were lower during August 2009 than February 2008 with PTVs making up 13.8% of the total count. Although nutrient loading and salinity increased since June 2008 the overall SPI score remained stable while pollution levels decreased.

From the results described above, the dominance of *N. frustulum,* during August 2009 indicated elevated salinity and problematic nutrient levels. According to Cholnoky (1968) this species is considered a nitrogen heterotroph and Hecky and Kilham (1973) state that *N. frustulum* is extremely tolerant of salinity and high alkalinity, and becomes abundant in brackish waters because competition from other diatom species is reduced. *F. geocollegarum* was also dominant, and is a freshwater taxon which seems to prefer more alkaline waters (pH 7.1 - 8.3), higher conductivity (458 - 1120 µS/cm), and more eutrophic conditions (early eutrophic to dystrophic) (Morales, 2002).

EFR O5

EFR O5 is situated approximately 4 km downstream of site 4 and 27 and was assessed during June 2012. The SPI score and ecological classification according to Van Dam et al. (1994) is provided in Table 9.

Table 9. Summary of diatom results at EFR O5

Variable	*Description*
pH	Alkaline
Trophy	Indifferent
Salinity	Fresh brackish
Oxygen	Continuously high
Nitrogen metabolism	Very small
SPI	11.4
EC	C/D

The diatom-based water quality was moderate with a SPI score of 11.4. The diatom community was dominated by *Fragilaria* species which occur in a range of waters ranging from oligotrophic to eutrophic. *E. microcephala* was dominant as well as *F. geocollegarum*. The dominance of these species during 2012 follows the same trend as 2010 and 2009. *Nitzschia* species were also dominant indicating increasing nutrient loads. Based on the TDI (Kelly and Whitton, 1995), organic pollution levels were elevated with PTVs making up 12.8% of the total count. These levels were slightly higher than during 2009, although these levels are not problematic.

Sample 3: Brandkaros

This site was sampled in June 2008 as part of a water quality monitoring and status quo assessment study of the Orange-Senqu River and associated tributaries (ORASECOM, 2009). The site is situated approximately 26 km upstream of Alexander Bay. The SPI scores and ecological classification according to Van Dam *et al.* (1994) for the sample is provided in Table 10.

Table 10. Summary of diatom results at Sample 3

Variable	***Description***
pH	Alkaline
Trophy	Eutrophic
Salinity	Fresh brackish
Oxygen	Moderate
Nitrogen metabolism	Elevated
SPI	12.4
EC	C

According to Koekemoer (2010) the sample was dominated by *F. sundayensis*, *Fragilaria elliptica*, *Fragilaria pinnata*, *Discostella pseudostelligera*, *Stephanodiscus agassizensis* and *S. minutulus*. Nutrients were elevated at this site. The presence of *S. agassizensis* indicated elevated turbidity (Taylor et al., 2007b).

The dominance of *F. elliptica*, *S. agassizensis* and *S. minutulus* also indicated that salinity was elevated at this site as these species have a preference for electrolyte-rich waters (Taylor et al., 2007b). However, the increased salinity could be due to the influence of the estuary. Organic pollution levels increased at this site if compared to sites upstream in the Orange River system although this is not reflected in the TDI (Kelly and Whitton, 1995) which indicated that PTVs made up only 1.5% of the total count. Centric diatoms are not included in the TDI and therefore this index has underestimated the impact of organic pollution levels. According to the ecological classification based on Van Dam et al. (1994) strong pollution levels were present. The sub-dominance of *Nitzschia* species indicated that nutrient levels were possibly increasing.

Sample 5 and 28: Alexander Bay

This site was sampled during June 2008 (Sample 5) and August 2009 (Sample 28) as part of a water quality monitoring and status quo assessment study of the Orange-Senqu River and associated tributaries (ORASECOM, 2009). The site is situated approximately 8 km upstream of Alexander Bay and was proposed as one of eleven transboundary water quality monitoring stations (Station 11). This site was deemed as a very important site for water quality monitoring as it represents the last site before the Orange River enters the ocean; is located just above the estuary and the important Ramsar wetland. According to ORASECOM (2009) water quality data at this point is crucial for the management of the river mouth Ramsar area. The SPI scores and ecological classification according to Van Dam et al. (1994) is summarised in Table 11.

Table 11. Summary of diatom results at Alexander Bay

Variable	***Description***	
	Sample 5	***Sample 8***
pH	Circumneutral	Alkalibiontic
Trophy	Eutrophic	Meso-eutrophic
Salinity	Fresh brackish	Fresh brackish
Oxygen	Moderate	Fairly high
Nitrogen metabolism	Elevated	Very small
SPI	10.9	16.5
EC	C/D	B

During June 2008 the dominant species were similar to Sample 3. Dominant species included *Discostella pseudostelligera*, *S. minutulus* and *F. sundayensis* with *Fragilaria elliptica* and *Fragilaria pinnata* being sub-dominant. Between Sample 3 and 5 there is an increase in salinity, as well as nutrients and organic pollution. PTVs make up 10.4 of the total count. Increased salinity is expected due to the close proximity of the estuary and the saline influence it would have on the Orange River. Although nutrients and organic pollution levels were elevated these levels were not problematic.

During August 2009 the diatom community indicated that flows were recently elevated (presence of *Encyonopsis microcephala* and *A. minutissimum*. The abundance of *Reimeria uniseriata* indicated that turbid conditions prevailed at the time of sampling as this species is able to grow under reduced light intensity (Taylor et al., 2007b). *Fragilaria geocollegarum* was also dominant indicating elevated salinity and increased eutrophic conditions within the system. *Epithemia adnata* was also dominant indicating that salinity has increased as this species extends into brackish biotopes (Taylor et al., 2007b). Flushing events are important for system recovery from deteriorated water quality as is evident from the SPI scores for June 2008 and August 2009.

3.6 Conclusions

3.6.1 Summary of results

A summary of the diatom results are provided in Table 12 based on a total count of 400 diatom valves. Table 13 provides the diatom-based ecological classification based on Van Dam et al. (1994).

Table 12. Summary of diatom results (2008–2012)

Site/Sample	*NB spec.*	*%PTV*	*SPI*	*EC*	*Pollution levels*
June 2008					
Sample 3	40	1.5	12.4	C	Strongly polluted
Sample 4	42	18.2	10.1	C/D	Strongly polluted
Sample 5	45	10.4	10.9	C/D	Strongly polluted
September 2009					
Sample 27	29	13.8	10.1	C/D	Very heavily polluted
Sample 28	17	1.3	16.5	B	Moderately polluted
November 2010					
OSAEH 28_5	22	6.5	14.9	B/C	Slightly polluted
June 2012					
EFR O5	36	12.8	11.4	C/D	Moderately polluted

Table 13. Generic diatom-based ecological classification

Variable	*Site*		
June 2008	Sample 3	Sample 4	Sample 5
pH	Alkaline	Alkaline	Circumneutral
Trophy	Eutrophic	Hyper-eutrophic	Eutrophic
Salinity	Fresh brackish	Fresh brackish	Fresh brackish
Oxygen	Moderate	Moderate	Moderate
Organically bound N levels	Elevated	Elevated	Elevated
September 2009	Sample 27	Sample 28	
pH	Alkaline	Alkalibiontic	
Trophy	Eutrophic	Meso–Eutrophic	
Salinity	Fresh brackish	Fresh brackish	
Oxygen	Continuously high	Fairly high	
Organically bound N levels	Continuously elevated	Very small	
November 2010	OSAEH 28_5		
pH	Alkaline		
Trophy	Mesotrophic		

Variable	***Site***
Salinity	Fresh brackish
Oxygen	Continuously high
Organically bound N levels	Very small
June2012	EFR O5
pH	Alkaline
Trophy	Indifferent
Salinity	Fresh brackish
Oxygen	Continuously high
Organically bound N levels	Very small

3.6.2 MRU Orange G: Fish River confluence to start of Estuary

Based on the diatom data the Orange River in this MRU seemed to be alkaline and calcareous. In the upper reaches of the MRU, upstream of Sendelingsdrift, mesotrophic to eutrophic conditions prevailed. Salinity levels seem elevated, along with nutrient levels which at times can become problematic. Organic pollution levels are very low and overall pollution levels are slight.

From Sendelingsdrift there was a deterioration in diatom-based water quality, mainly due to elevated organic pollution levels and salinity. Nutrient levels were elevated and became problematic at times. In the lower reaches of the MRU water quality follow the same trend, although salinity increased slightly, which was expected due to the proximity of the Estuary. Elevated flows do play an important role in ameliorating the effects of deteriorated water quality and allows for system recovery. The overall EC for this reach was set at a C.

4. Geomorphology

The physical structure of a river ecosystem is determined by geomorphological processes which shape the channel. These processes determine the material from which the channel is formed, the shape of the channel and the stability of its bed and banks. The channel geomorphology in turn determines the substrate conditions for the riverine fauna and flora and the hydraulic conditions for any given flow discharge. Structural changes to the river channel (damage to the riparian zone, sediment inputs from catchment erosion or reservoir induced changes in the flow regime) can cause long term irreversible effects for biota (O'Keeffe, 2000; Kochel, 1988). Geomorphology thus provides an appropriate basis of classification for describing the physical habitat of riparian and aquatic ecosystems.

The PES of the EFR sites was assessed using the Geomorphological Driver Assessment Index (GAI) (Rountree and du Preez, in prep).

The reach in which EFR O5 is situated is described as follows:

- Weakly braided/multichannel reach (at moderate flows). During the time of the site visit the large backwater channel on the southern (South African) bank was connected to the main channel (outflow point was at approximately 28°4' 18.82" S; 16°57' 52.24" E)
- Although the bar and channel bed consists of large cobbles with isolated patches of silty fines (lee/slackwater deposits such as in the backwater channel), coarse sands and gravels are largely absent from the site. One area of exception is along a narrow strip immediately adjacent to active channel. This zone of sand and cobbles is probably a consequence of high level energy zone (cobble deposit) and high suspended load arising from the Orange River (accounting for the sand) during floods.

The Orange River Reconnaissance Study, undertaken between 1906 and 1914, yielded annotated maps describing the area around EFR O5 at the turn of the last century. Comments on the sediment distribution through this area noted a variety of sedimentary deposits, from shingly beds (at the upstream Vioolsdrift) to further downstream where the Orange River is described as having a very sandy bed. Closer to EFR O5 (around the Richtersveld) the bed is noted as 'very rocky' with 'rough and stony' banks. Downstream of EFR O5 it was noted that the banks were well-wooded in places 'with mimosa and bastard ebony', and general notes indicated that an 'abundance of firewood (was) to be had all along the Orange River'. Close to the mouth (along the wetland estuary) 'great quantities of debris of trees etc. lie on banks'. This information provides valuable insights into the reference condition.

The aerial photographic record for the study area began in 1943 (limited coverage) and then full coverage was available on the 15 July 1964, 08 May 2005, 22 November 2006, 07 August 2009 and 14 May 2011 (Figure 4). The historical imagery documents a steady increase in the number and extent of the small wooded bedrock core bars (small islands) immediately upstream of EFR O5, but then between 2005 and 2011 there was a large decrease in the number and extent of these small bars. This reduction (reset) was probably due to erosion during very high flood flows; removing vegetation and scouring the sediment accumulated on the islands. These floods also activated a large secondary channel alongside the southern bank (the backwater on the southern bank at the EFR site).

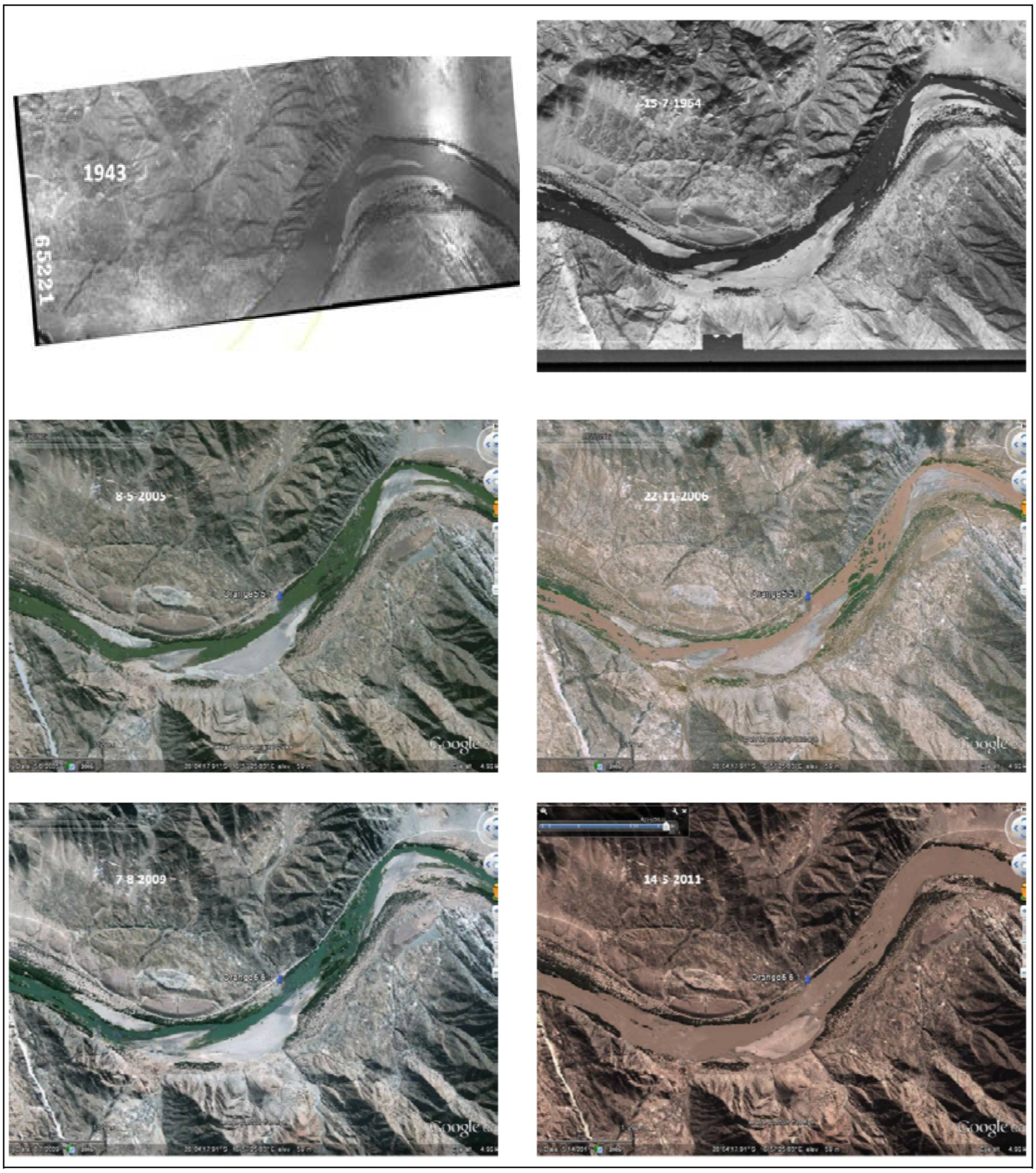

Figure 4. Historic aerial photography of the river reach represented by EFR O5

The Orange River is one of the world's most turbid rivers; and much of this sediment is believed to originate from soil erosion, particularly from the Karoo formation in the Caledon catchment. The sediment flux prior to the building of large dams was ten times greater than the mean Holocene mud flux. This rapid increase of sediment during historic times is accounted for by estimates of soil erosion in the catchment. The bulk of sediment production is expected to have shifted from the areas of high relief and rainfall of the upper Drakensberg escarpment to the intensely cultivated lands of low relief in the moderate to high rainfall areas of the eastern catchment and, to a lesser extent, the grazing areas of the southern Orange River catchment (Compton et al, 2010). The Orange River has thus been undergoing a phase of extremely high sediment loads associated with this widespread erosion phase in the upper catchment (triggered by landuse changes). The slight reduction in suspended load caused by upstream dams may cause a slight tendency towards more natural conditions.

The channel is exposed to a high suspended load, due primarily to erosion in the upper Orange (especially Caledon) catchment. The hydrology report (this volume) indicates that "small and medium floods have been heavily impacted on due to many large dams in the catchment" and that even floods up to the 1:10 year size can be lost (attenuated) in the system. The reduced flow volume (the mean annual runoff (MAR) is about one third of the virgin flow volumes) and critically reduced small and moderate floods decrease the ability of the river to flush out sediment and maintain the river morphology. Very large floods are probably not affected however, so reset events (as indicated by the historical record) can still occur.

The upstream Fish River (although itself having very reduced volumes) introduces some coarse sediment and flood variability back into the lower Orange River, thus ameliorating some of the flow regulation impacts from the Orange/Vaal River system. Alluvial diamond mining occurs in places in the lower Orange near the EFR site, but these activities are outside of the river and have not had a direct impact on channel form.

The PES is in a B/C category (79%). This relatively high PES score is due to the resistant nature of the channel form in this reach, as well as to the ameliorating impacts on flow (especially floods) and sediment delivery afforded by the upstream Fish River tributary.

5. Riparian vegetation

5.1 Data availability

The following data were utilised for assessment of riparian vegetation at EFR O5:

- Satellite images (Google Earth, May 14 2011) and historic aerial photos (1943, 15 July 1964, 08 May 2005, 22 November 2006, 07 August 2009 and 14 May 2011) of the respective reach;
- hydrology specialist report (Technical Report 31);
- EcoRegion class and associated information;
- geomorphic Zone classification;
- fluvial geomorphology report (Chapter 4) and GAI;.
- biomes and vegetation types of South Africa: Rutherford and Westfall (1986); van Wyk and van Wyk (1997) and Mucina and Rutherford (2006);
- historical botanical descriptions of the area (Skead, compiler 2009);.
- South African National Biodiversity Institute (SANBI): Plant of Southern Africa online database (based on several herbaria collections);
- data collected during field visit (15 June 2012);
- water quality specialist report (Chapter 3);
- IHI (Index of Habitat Integrity) (Chapter 9).

5.2 Methods

The Vegetation Assessment Index (VEGRAI) Level 4 (Kleynhans et al., 2007) was used to assess the PES of riparian vegetation. Key riparian indicator species were surveyed onto a calibrated hydraulic profile in order to assess flow requirements (see Appendix A for species list). Figure 5 indicates the extent of the assessment area for VEGRAI which included approximately 250 m upstream and 320 m downstream of the cross-section marked XS in Figure 5.

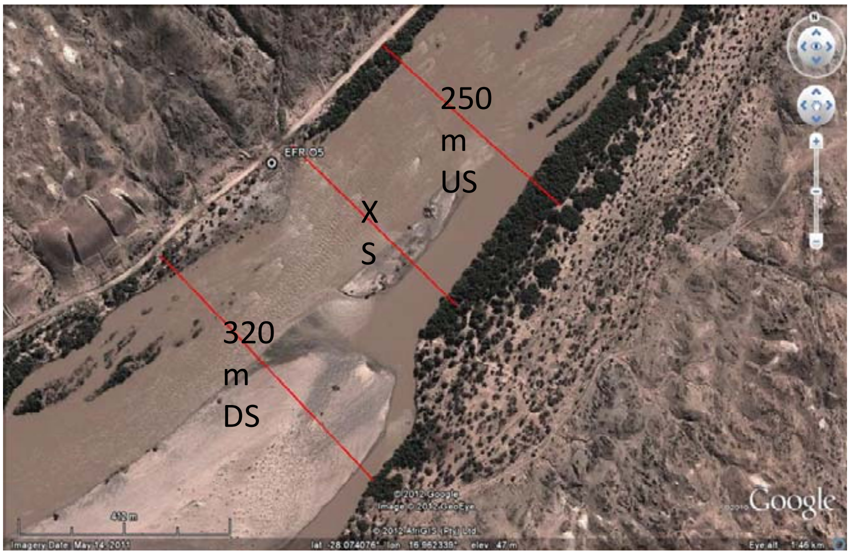

Figure 5. Extent of sampled area for VEGRAI

5.3 Present ecological state

A comparison of historical aerial photos from 1943 to 2011 Google Earth images, indicates little change to woody vegetation (structure and cover) (Figure 6).

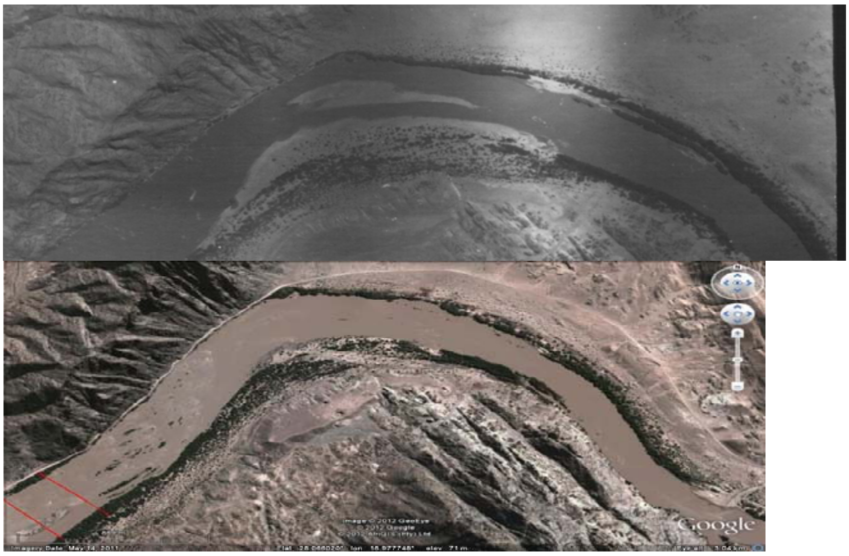

Figure 6. Aerial photos from 1943 (above) compared to 2011 Google Earth images (below)

The assessed area at EFR O5 is contained within Lower Gariep Alluvial Vegetation. This vegetation type is poorly protected and has 50.3% remaining. Consequently it has a conservation status of "Endangered". Current conservation target is set at 31% with only 5.8% currently conserved (Mucina and Rutherford, 2006). About 50% of this vegetation type has been transformed for agricultural activities (mostly grapes and vegetables). Alluvial terraces and banks are dominated by woody riparian thickets (mainly *Acacia karoo, Ziziphus mucronata, Searsia pendulina*) or stands of *Tamarix usneoides* or reeds (*Phragmites australis*). Cobble or boulder features are characterised by a mix of woody species (*T. usneoides, Gomphostigma virgatum*) and sedges (*Cyperus longus,* and *C. marginatus*). Frequently flooded alluvia are open or grassed (*Cynodon dactylon* mainly) and *Salix mucronata* is also common on frequently inundated alluvia.

The expected reference condition of riparian vegetation for each of the zones is as follows:

- Marginal zone: Expect a mix of open alluvia or cobble/boulder and vegetated areas. Vegetation, similarly, should be a mix of woody (*G. virgatum*, *S. mucronata* subs. *mucronata*) and non-woody (*P. australis*, *C. marginatus*, and *C. longus*) vegetation.
- Lower zone: Expect the same as the marginal zone, with the addition of *T. usneoides*.
- Upper zone: Terraces should be well vegetated with small percentage of open areas. Vegetation will be a mix of reed beds (*P. australis*) or woody thickets (*A. karoo*, *Z. mucronata*, *S. pendulina* mainly).
- Upper zone macro channel bank (MCB): Banks should be well vegetated and dominated by woody riparian thickets, with dominant species as outlined above. Also expect *Euclea pseudobenus*.
- Floodplain: Similar to bank species with some terrestrial woody and shrub species.

The PES for EFR O5 is 82.1% (category B) for riparian vegetation (Table 14) with an average confidence of 3.7 (high). A breakdown of the overall score into different zones (Table 14) shows that the marginal and lower zones are least impacted (A/B and B ecological category (EC) respectively) and the upper zone, bank and floodplain (B/C and C ECs) are the most.

Table 14. VEGRAI score for EFR O5

Riparian vegetation zones	***PES % and EC***	***Confidence***
Marginal	88.9% (A/B)	3.8
Lower	85.7% (B)	3.8
Upper	79.2% (B/C)	3.8
Upper MCB	76.8% (C)	3.5
Floodplain	77.5% (B/C)	3.5
VEGRAI (%)	82.1%	
VEGRAI EC	B	
Average Confidence		3.7

The PES of riparian vegetation for each of the zones is as follows:

- Marginal zone: Mostly open bedrock with some alluvium. *P. australis* (common and localised), *S. mucronata*, *G. virgatum* (common and widespread) and *C. longus* (common localised) are dominants.

- Lower zone: Similar to marginal zone with the addition of *S. mucronata* in large numbers (especially recruiting saplings) and adults where alluvial bars have formed.
- Upper zone: Sparse, mostly cobble beds with some back channels where fine alluvia have collected. Back channels support wetland and aquatic species such as *C. longus*, *C. marginatus*, *Bolboschoenus glaucus* and *Potamogeton pectinatus* and *P. schweinfurthii* respectively.
- Upper zone MCB: Alluvial and dominated by dense woody vegetation. Mostly *A. karoo*, *Z. mucronata*, *S. pendulina* and *E. pseudobenus*. Some *P. glandulosa* recruitment is evident.
- Floodplain: Alluvial, left bank only: continuation of MCB species with the addition of terrestrial species. *Lycium* spp. common.

6. Riverine fauna

The riverine fauna component is not usually included in EFR assessments as it is not a sensitive indicator. This is however not the case in dry or desert landscapes. Assessment methods for determining the PES of riverine fauna was developed during the GIZ study undertaken during 2010 and further development of the method has been undertaken during this study.

6.1 Methods

Since there is no established method or model to determine the ecological state of the riverine fauna component, a process was developed for this aspect. The main components of this process that are considered comprise the following aspects:

- expected riverine fauna species to the area;
- probability of occurrence;
- quality of habitat present.

The first two aspects were obtained from literature, which included species atlas projects and field guides. The 'Quality of habitat present' was assessed during the field trip. Google Earth views and photos of the sites were obtained and are used as important reference material.

The current situation, as experienced during the field trip in June 2012, was used to establish the PES (Present Ecological State). The survey was undertaken during June 2012 in the lower Orange River. The results of this component of the study (riverine fauna) comprise of detailed assessment of the riverine habitats depicted by rudimentary plan view drawn at the sites, backed by photos of the aspects of local habitat. These maps were used to identify potential habitats and associated with potential fauna species prone to utilise these habitats. The habitats were used to supply a benchmark for the PES, and by assessing the probable anthropological changes to the system, the reference conditions could be established. The main survey results were thus incorporated into the PES.

6.2 Riverine habitats and associated riverine fauna

In order to assess the biota according to their intolerance regarding water level or flow changes, the following reasoning was used:

- the dependency can be related directly to the aquatic habitats for shelter, breeding and food, or to the riparian vegetation for these services;
- should the riverine structure and function be compromised by flow requirements, this will also influence the associated fauna.

These attributes are functions of the main riverine habitats, and can be defined by the finer habitats (biotopes) in the following groupings.

a) Aquatic habitats

- Flowing habitats: runs, rapids and riffles. Habitats completely dependent on flow and water level.
- Slow flowing or non-flowing habitats: Instream pools and backwaters. Habitats dependent on water level.
- Connected wetlands: Backwaters and floodplains. Habitats dependent on periodically inundation. Seepage wetland feeding into drainage. Seepage wetland: From damp/wetted soils (floodplain/swamp/vlei (marsh)) to partially shallowly inundated soils (<10 cm) with emergent sedges, hydrophytic grass, tussock grass.

The following biotopes are all relevant to the different aquatic habitats:

- exposed shoreline: Water edge to partially shallowly (<10cm) water inundated soils (sandy, muddy or gritty);
- reed bed, reed islands or dense tall grass: Transitional from damp land, through shallow water to inundated in deeper water;
- grassy edge connected to water: Edge and bank of stream and floodplains. Dense cover of grass and forbs, grass may be inundated shallowly;
- Deep open water: For hunting and shelter.

b) Riparian systems

Trees and embankments which form habitats dependent on groundwater associated with water levels in the river.

- Vertical or remote sand banks - Vertical or remote sand banks: Eroded alluvial sand river banks to form vertical faces or gullies - mostly tunnelling for nesting or shelter; or flat sandbanks removed from river edge.
- Wooded bank: Dense shrubs and tall continuous riparian trees, lodged flood debris, tangled roots and forbs.

In placing riverine fauna into potential habitat groupings, a few rules have been created to assist with this categorisation and is outlined below.

- To be considered as a riverine species, at least a part of the life stage must be dependent on the riverine habitat. For instance, in the case of toads, the adults can live in a terrestrial environment, but the larvae (tadpoles) need an aquatic environment as they develop.
- Although water dependent, certain wetland species are better adapted to a non-riverine environment (pans, dams, etc.) but will periodically utilise the riverine habitat to feed, breed

or shelter. Nomadic species, such as ducks and grebes will resort to riverine habitats should their traditional wetland dry up or should they be on transit to other areas.

- The sensitivity of a species could also depend on the sensitivity of its food species to water level/flow changes. Certain riverine species feed on macro-invertebrate, hydrophytes (water-living plants) or fish. These food organisms are also, in varying degrees, dependent on the aquatic environment, and this level of dependency will be reflected in the ecological sensitivity category of the riverine vertebrate.
- In most cases, the habitat utilised for feeding, sheltering or breeding, e.g. vegetation or substrate, are dependent on the level of water in the river. Marginal vegetation, should it be large riparian trees or sedges, are dependent on the water level in the riverine system, either subsurface or surface flows.
- The duration of habitat presence will vary from ephemeral to perennial systems and this will also impact on the viability of the habitat for different species. Ephemeral systems can create flooded areas and pools that remain for a period, and will be utilised by riverine species as long as they are viable. Subsurface water in these systems is sometimes lasting much longer and is important to riparian vegetation.
- Large, irregular flood events create both temporary and semi-permanent habitats which animals will react to. The temporary systems are floodplains, marginal pools and oxbow lakes, while the more permanent ones are vertical sandbanks and floodplain vegetation which is supported by subsurface water.

An important variation regarding the riverine rule, is the fact that the Orange River, are riverine systems that drains extremely dry landscapes. The linear ecosystem that comprises the aquatic and riparian zones is an important biotope for more than just true riverine fauna. Terrestrial fauna species present in the riverine system, do not have the choice to move out of the system as their counterparts do in more mesic systems. Thus, should a non-riverine animal species take on the riverine system as an abode, it will become dependent on the biotope, since there is no other option.

6.3 Present ecological state

The PES and associated changes from reference conditions are provided in Table 15. Using the modelled procedure, the PES of the riverine fauna of EFR 05 has been determined as a Category B (83.2%).

Table 15. EFR 05: PES and changes from reference conditions for the Orange River

Habitats	Reference conditions	PES
Vertical or remote sand banks.		
	Extensive sand banks, maintained by scouring and deposition during floods.	Sand banks reduced due to infestation of reeds and *Prosopis*; sandbanks stabilized by vegetation.
Exposed shoreline - shallow edges		
	Large stretches of exposed shorelines, maintained by scouring and deposition during floods.	Stretches of exposed shorelines reduced due to colonization by reed beds, bank stabilization due to lower flow variability and loss of higher flooding incidence.
Reed bed or reed islands		
	Few patches of reed beds, scoured by floods.	Reed beds increase substantially in extent due to less scouring by floods and increase in nutrients.
Grassy edge connected to water		
	Grassy edges and grazing lawns developed on alluvial banks during low flow periods.	Grassy edges stable due to less scouring by floods.
Wooded bank - shrubs and tall riparian – continuous		
	Moderately dense, continuous riparian corridor on macro channel bank, lower plant cover in river bed due to flood scouring.	Riparian corridor reduced and replaced by agriculture or alien *Prosopis*; lower stable flows also reduced the extent of the riparian corridor.
Seepage wetland feeding into drainage		
	Very little seepage wetland, floodplains present and create wetlands after major floods.	Very little seepage wetland, floodplains influenced by agriculture, less and lower floods also reduced the frequency of floodplains inundated.
Open water - deep for hunting and shelter		
	Good open water in the form of deep pools maintained by annual flood scouring; hold water during no-flow periods.	Deep pools silted up due to reduction in larger scouring floods.

Appendix B incorporates plan view maps with habitats of EFR O5 in the Orange River. Species lists of riverine fauna occurring at EFR O5 are provided in Appendix A in Technical Report 28.

6.4 Determining consequences of flow scenarios

Conceptual approach to determine the riverine fauna response (excluding instream) to different flow scenarios:

- Identify faunal species depending on the riverine ecosystem: Riverine species refer to animal species where their dependency can be related directly to the aquatic habitats for shelter, breeding and food, or to the riparian vegetation for these services. Since many riverine species are relatively mobile (birds and larger mammal species), they can migrate whenever circumstances becomes harsh. However, certain animal species are less mobile and will thus be influenced more by local environmental changes. These species can be used as key or indicator species.

- Obtain distribution data of these riverine animals: By making use of species distribution maps and atlas data, it can be established which animals should be present in the areas of concern. With detailed distribution records available, the probability of occurrence and even the abundance can be determined.
- Verify the habitat requirements of these assemblages (aquatic, semi-aquatic and riparian): Habitat requirements per animal species can be obtained from a wide spectrum of literature and expert knowledge.
- Map the habitat types at the EFR sites: During the field surveys, different habitat types will be delineated on Google Maps and any other aerial maps available. Views of different water levels per site will enhance the effectiveness of the maps for scenario evaluations.
- Model habitat change with changing water levels: By linking the mapped habitats and its position relating to water levels, changes in habitat extent and functionality could be modelled relating to altering water levels. Links with the fish, macro-invertebrate and riparian vegetation evaluation are essential as these groups determine food availability, and presence of shelter and nesting habitats.
- Establish species change (diversity and abundance) for the riverine fauna reacting to flow scenarios: Whenever the habitat integrity of the site is established, the reaction of the riverine fauna to changes in habitat composition could be determined, signifying the presence or absence of species, or a level of abundance relating to habitat quality.

7. Macro-Invertebrates

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7.1 Background

A key component of EFR assessment is the response of macroinvertebrates to modified flow scenarios. Aquatic macroinvertebrates are used worldwide to monitor the ecological health of river systems, and are a key component of the Orange-Senqu Biological Monitoring Programme (ORASECOM, 2011b). This specialist report forms part of the EFR assessment, and concerns the Present Ecological State of aquatic macro-invertebrates in the lower Orange.

7.2 Aims

The aims of this report were to define the Present Ecological State of aquatic macro-invertebrates within one MRUs in the Orange River (Figure 1), and to develop a method to predict the response of aquatic macro-invertebrates to modified flow scenarios in the Orange River.

7.3 Available data

The field survey for this report was undertaken between 15–18 June 2012. Macro-invertebrates were collected from one site in the lower Orange River (Figure 1).

The main sources of information on macro-invertebrates in the Orange River that were used in this assessment comprised the following:

- November 1995: Macro-invertebrates were collected at the confluence with the Boom River, 14.5 km upstream of EFR O5, by Mark Chutter, as part of an assessment of EFRs of the middle and lower Orange River, undertaken by the Orange River Environmental Task Group (Chutter, 1996).
- January 2004: Macro-invertebrates were collected 10 km downstream of the EFR O5 by Rob Palmer, as part of the Environmental Assessment of irrigation development at Sendelingsdrift (Palmer, 2004).

- November 2010: Aquatic macro-invertebrates were collected at the confluence of the Boom River (OSAEH 28.5), 14.5 km upstream of EFR O5 by Marie Watson, as part of the Orange-Senqu baseline monitoring programme (ORASECOM, 2011b).

The confidence in available data is provided in Technical Report 29.

7.4 Methods

7.4.1 Abundance

The determination of abundance of macro-invertebrates was based on Dickens and Graham (2002) and outlined below.

Abundance of macro-invertebrates in each sample was classified into five categories as follows:

1 Abundance: 1

A Abundance 2 to 9

B Abundance 10 to 99

C Abundance 100 to 1,000

D Abundance > 1,000

7.4.2 Frequency of occurrence

The frequency of occurrence (FROC) of each macro-invertebrate taxon under natural (reference) conditions was based on historical information and professional judgement and classified into five categories according to Kleynhans and Louw (2007) as follows:

1 = Present at very few sites (<10%)

2 = Present at a few sites (10 to 25%)

3 = Present at about 25 to 50% of the sites

4 = present at most sites (50 to 75%)

5 = Present at almost all sites (>75%)

7.4.3 South African Scoring System (SASS)

Macro-invertebrates in the Orange River were collected and analysed using the South African Scoring System version 5 (SASS5) (Dickens and Graham, 2002). This is a rapid method of quantifying the health of perennial rivers and streams, and is based on the presence of major macroinvertebrate groups (mostly families), each of which have been allocated a "sensitivity" value which ranges from 1 (tolerant) to 15 (highly sensitive). The scores for each SASS5 taxon recorded at a site are added to obtain a Total Score, and the total is divided by the number of taxa to obtain an average score per taxon (ASPT). The total score and ASPT are used together to indicate the health of the river or stream. The method cannot be used to predict the likely biological responses to changes in stream flow.

7.4.4 *Habitat suitability*

The macro-invertebrates found at a site often reflect the diversity and quality of habitats available, so the interpretation of biomonitoring data was enhanced by recording the quality of habitats sampled. In this study the quality of each habitat sampled was assessed in terms of the suitability for aquatic macro-invertebrates using a simple, six-point scale:

0=Absent

1=Very Poor

2=Poor

3=Moderate

4=Good

5=Highly Suitable.

Each habitat category was assigned weighted importance value that varied according to the geomorphological stream type. The weighted values were multiplied by the suitability rating (0–5), and the results were expressed as a percentage, where 100% = all habitats highly suitable. The percentage values were converted to a category (A to F), to allow easy comparison among sites or sampling events.

7.4.5 *Macroinvertebrate Response Assessment Index*

The method to define the PES of macro-invertebrates and their response to modified flow scenarios in the Orange River was based on the Macroinvertebrate Response Assessment Index (MIRAI) (Thirion, 2007). This index quantifies the extent to which the present (observed) invertebrate assemblage and abundances differ from the reference (natural) assemblage and abundances. The MIRAI comprises 32 metrics which are each ranked and rated in terms of their importance in defining present state, and in terms of the changes from reference conditions. The metrics are grouped in terms of the following key ecological drivers:

1) ***Flow*** Modification, within each of the following flow categories:
   - Very fast flowing water (>0.6 m/s)
   - Moderately fast flowing water (0.3–0.6 m/s)
   - Slow flowing water (0.1–0.3 m/s)
   - Very slow flowing/standing water (<0.1 m/s)

2) Habitat ***Modification*** within each of the following categories:
   - Bedrock and boulders: substrates (>256 mm)
   - Cobbles and Pebbles: substrates (16–256 mm)
   - Vegetation: inundated fringing and aquatic vegetation
   - Gravel, Sand and Mud: substrates (<16 mm)

- Water column: water surface and water column

3) ***Water*** Quality ***Modification*** within each of the following categories:
   - Highly sensitive taxa
   - Sensitive taxa
   - Tolerant taxa
   - Highly tolerant taxa
   - SASS5 Total score
   - SASS5 ASPT

4) ***System Connectivity and Seasonality*** within each of the following categories:
   - Impact on migratory taxa
   - Impact on seasonal distribution

Each metric and each metric group listed above is:

1) Ranked in terms of its importance for defining the ecological state of aquatic macroinvertebrates at a particular site or ecological zone.
2) Weighted on a percentage scale, where Rank 1 = 100%, and other metrics are then ranked as a percentage relative to the most important metric.
3) Rated separately for each site or ecological zone under consideration. A six-point rating system was used, as follows:

   0=No change from reference.

   1=Small change from reference.

   2=Moderate change from reference.

   3=Large change from reference.

   4=Serious change from reference.

   5=Extreme change from reference.

7.5 Present ecological state

7.5.1 Reference conditions

The expected composition, abundance and Frequency of Occurrence (FROC) of aquatic macro-invertebrate in the Orange River at EFR O5 was based on information presented in a baseline report on monitoring of the nearby site OSAEH 28.5 (ORASECOM, 2011b). The reference list was extracted from the South African Department of Water Affairs Resource Quality Services (DWA: RQS) preliminary aquatic macro-invertebrate FROC Database, prepared by Christa Thirion. The list was modified to include additional taxa that have been recorded in the area, such as Crambidae (Chutter, 1996), and Dipseudopsidae (Mey, 2011). Reference SASS5 results were based on species with an expected FROC of 4 or higher, and the expected FROC of selected taxa, namely Tipulidae, Hydrophilidae and Sphaeridae, was reduced from 4 to 3 to obtain a more realistic total SASS Score. The following reference SASS5 scores were obtained:

SASS5 Score:	181
Number of Taxa:	30
ASPT:	6.0

The most abundant aquatic macro-invertebrate trophic group in the middle and lower Orange River are filter-feeders. Common and abundant filter-feeders include several species of blackflies (*Simulium* spp.), the midge *Rheotanytarsus fuscus*, the mayfly *Tricorythus discolor*, various species of hydropsychid caddisflies, bivalves *Corbicula fluminalis* and *Unio caffer*, the sponge *Ephydatia fluviatilis* (complex), the bryozoan *Plumatella* sp. and the Caenid mayfly *Clypeocaenis umgeni*. Although many filter-feeding species in the Orange River are found in rivers elsewhere, their abundance in the Orange River is unequalled among rivers in southern Africa (de Moor pers. comm.). The overwhelming abundance of filter-feeders in the lower Orange River highlights the importance of fine particulate material in the functioning of the river. It follows that any change to the quantity or quality of suspended particles will affect the invertebrate community, and ultimately, the river as a whole.

7.5.2 Present ecological state

The macro-invertebrate PES in the lower Orange River in June 2012 was rated as Category B/C (Table 16). Similar results were obtained using the ecological traits method (80%) (Technical Report 28), and the MIRAI method (78%). The confidence in the assessment was rated as Moderate (3/5) because of the uncertainly concerning the reference state. The rankings and weightings applied to the MIRAI metrics in this report prioritised the presence of taxa with a preference for moderately fast-flowing water (0.3–0.6 m/s), fringing and aquatic vegetation, and moderate sensitivity to water quality deterioration. Low priority was given to invertebrate abundance because of the large variation in invertebrate abundance expected under natural conditions. Variation in abundance is made more extreme in this MRU because of periodic inputs of high sediment loads from the Fish River. Weighting of ecological traits prioritised the importance of water quality (22%), habitat quality (15%) and filter-feeding (15%).

Table 16. Summary of aquatic macro-invertebrate information and PES in the Orange River

MRU	***MRU Orange G***			
Site	***OSAEH 28_5***	***S1***	***OSAEH 28_5***	***EFR O5***
Reference	Chutter (1996)	Palmer (2004)	ORASECOM (2011b)	This Study
Date	Nov 1995	Jan 2004	Nov 2010	Jun 2012
Flow (m^3/s)	-	-	-	Moderate
Biotope suitability	-	-	-	61% (B)
SASS5 score	160	152	150	125
No of taxa	25	25	24	21
ASPT	6.4	6.1	6.3	5.9
PES: Ecological traits (Category A-F)				**80% (B/C)**
PES: MIRAI (Category A-F)	**-**	**-**	**79% (B/C)**	**78% (B/C)**

A total of 21 SASS5 taxa was recorded at EFR O5, compared to 30 expected. Taxa expected but not recorded included Simuliidae, Tricorythidae, Corbiculidae, Leptoceridae, Gerridae and Veliidae. The suitability of instream habitats was Good (61%), but macro-invertebrate populations were generally very low. The life span of most adults was moderate (3 to 6 months), and only one taxon with a long adult life span was recorded. Six of the 21 SASS5 taxa were air-breathers, indicating well-oxygenated conditions. The most common functional feeding groups were Collector/Gatherers and Predators. Filterers were noticeably rare, and comprised low populations of sponges and hydropsychid caddisflies. Most taxa had a preference for slow to moderate current speeds, and only one taxon had a preference for fast current speeds. Four categories of habitat preferences were represented, and the highest number of taxa was had a preference for cobble habitats. No taxa with a preference for warmer water were recorded. The diversity of invertebrates sensitive to water quality deterioration was high, with six sensitive taxa recorded, including hepatageniid and leptophlebiid mayflies. No alien invertebrates were recorded.

The key reasons for the PES of macro-invertebrates in MRU Orange G are described below.

- **Elevated low flows**: Analysis of historical flow data from Boegoeberg Dam showed that before impoundment the driest month was September, during which flows were less than 15 m^3/s in nearly 40% of the years between 1933 and 1969 (Palmer, 1997b). It is unlikely that much or any of this water would have reached the mouth. This conclusion is supported by the natural diversity of aquatic macroinvertebrates in the lower Orange River, which is remarkably low for a river of this size. Most macro-invertebrate taxa recorded from the study area are hardy and widespread and typical of seasonal rather than perennial systems (Palmer 1996, Mey, 2011). The low species richness is associated with the extreme conditions which characterise the middle and lower Orange River under natural conditions, as periodic drying of the lower reaches is likely to have precluded the evolution of a typical lowland fauna (Chutter pers. comm.). A similar situation is found in the lower Colorado River, Arizona (Ward et al., 1986). Fauna in such rivers has evolved life-histories to cope with droughts and floods (Chutter and Heath, 1993). A large proportion of the taxa in the lower Orange River withstand drying, and these include Bryozoans, the sponge *Ephydatia fluviatilis*, the midge *Polypedilum* sp., caenid mayflies, and Bdelloid rotifers. Circumstantial evidence also indicates that the eggs of the pest blackfly S. *chutteri* undergo extended periods of diapause. The only abundant macro-invertebrate taxon in the vicinity of Sendelingsdrift in August 1994 was the pest blackfly *S. chutteri* (Palmer, 1995). High numbers of this species are attributed mainly to hydropower releases in winter, which have elevated dry season low flows and enable this species to overwinter as larvae (Palmer, 1997a). Elevated low flows have had the biggest influence on modifying the invertebrate PES of the middle and lower Orange River.

- **Reduced high flows:** Analysis of historical flow data from Boegoeberg Dam showed that annual high flows were usually well over 1,000 m^3/s, but impounding the river has eliminated these annual high flow events (Palmer, 1997b). High flows mobilise and deposit sediments and areas of newly deposited sediments are colonised by pioneer plants, such as *Phragmites* reeds, when flows recede. The reeds provide important habitat for aquatic invertebrates inhabiting slow-flowing water, and decomposition of their leaves is likely to provide an important source of organic material, particularly when the reeds are burnt. *Phragmites* reeds are currently among the most characteristic feature of the riparian vegetation along middle and lower Orange River, but historical photographs show that reeds have not always been abundant. Photographs taken as recently as 1976 show an almost complete absence of reeds. The dramatic spread of reeds has been attributed to the stable flow conditions following impoundment (Davies et al., 1993). However, there are sections of river, particularly in the lower reaches, where reeds are absent except where the bank is disturbed. For example, upstream of the mouth, the riparian vegetation is dominated by the Cape willow (*Salix mucronata*), except at a pumping station, where *Phragmites* sp. is abundant (Palmer, 2004). It is clear that *Phragmites* reeds are pioneer plants that are quick to colonise disturbed areas, and that the abundance of reeds in the middle and lower Orange River is associated mainly with physical disturbance of river banks rather than more stable flows. This conclusion may apply to river banks but less applicable to islands, which are generally less accessible and therefore less disturbed. The islands at EFR O5 were dominated by *Phragmites* reeds, whereas river banks were colonised mainly by trees. The dominance of reeds on these islands may well be a response to more stable flows following impoundment, and in particular, the reduced magnitude of high flows.
- **Aseasonal releases:** Impoundments typically delay the onset of high flows because water is first stored before operational rule allow it to be released. Analysis of historical flow data from Boegoeberg Dam showed that before impoundment the driest month was September, and the first spring freshet was most often (60% of years) in November (Palmer, 1997b). After impoundment there was no winter drought and no consistent spring freshet, and high flows were most often in March (i.e. delayed by four months). This is at the end of the rainy season, when water is released from Vanderkloof Dam to provide

buffering capacity for floods, anticipated the following season. The implications of this on aquatic macro-invertebrates are unknown, but likely to be significant.

- **Increased cyanobacteria:** Blooms of potentially toxic blue-green algae occur periodically in the middle and lower Orange River, usually following overturn of Vanderkloof Dam towards the end of summer (Allanson and Jackson, 1983). Blooms of *Microcystis* in April 1993 and 1994 corresponded with a significant reduction in abundance of several taxa in the Orange River near Upington. Taxa whose abundance dropped significantly during algal blooms included the pest blackfly *S. chutteri,* the limpet *Burnupia sp,* the beetle *Aulonogyrus,* turbellaria flatworms and the stonefly *Neoperal spio* (Palmer, 1997b). These observations suggest that cyanobacterial blooms could have a significant impact on the diversity and abundance of aquatic macro-invertebrates in the middle and lower Orange River.
- **Increased salinity:** The Orange River Replanning Study predicted that salinities downstream of Vioolsdrift will increase significantly from 1995 values of 311 mg/l, to values varying between 500 and 1,500 mg/l by 2030 (van Veelen and van Heerden, 1998). These changes are likely to have significant impacts on aquatic invertebrate composition and abundance.
- **Increased woody snags:** Woody snags provide an important substrate for aquatic macroinvertebrates, particularly downstream of Sendelingsdrift, where there are no further riffles or rapids. Snags also play an important role in protecting banks from erosion by extending the current boundary layer. A study of woody snags in the Satilla River, southeastern Georgia, found that although snags constituted a small habitat surface (4% of the total), snags supported 60% of the macro-invertebrate biomass and 16% of the secondary production (Benke et al., 1985). Although several species are associated with snags in the Orange River, the only taxon found almost exclusively on snags is the large elmid beetle sp. 'C', thought to be *Potomadytes brincki*. This species is the only known obligatory wood gauger (feeder) in the Orange River. The species is vulnerable to change, both because of its specialised diet and because of its longevity. Reduced high flows from impoundments appear to have led to increase in woody vegetation, and this is likely to have benefited this species.
- **Competition from alien species:** The snail *Physa acuta* was first recorded in the Orange River System at Boegoeberg Dam in 1971 (de Kock et al., 1974). This species has subsequently spread dramatically; in 1993 specimens were recorded near Upington and Augrabies Falls, and in 1994 specimens were recorded near the river mouth (Palmer, 1996). This species is suspected of outcompeting indigenous snail species.

7.6 Limitations

7.6.1 Reference conditions

There is limited information on aquatic macro-invertebrates in the study area before impoundment and associated large-scale irrigation development. The only data available on aquatic macro-invertebrates in the lower Orange River before the construction of Vanderkloof and Gariep dams in the 1970s was a snap sample collected at Onseepkans in December 1960 (Agnew, 1965).

7.6.2 MIRAI

The weightings and ratings applied to MIRAI metrics at a particular site should remain constant, so for consistency the same or similar values used for the ORASECOM baseline monitoring conducted at the confluence of the Boom River (Site OHAEH 28_5), should have been applied in this study (ORASECOM 2011b). However, the 'presence of taxa with a preference for very fast-flowing water' was ranked as the most important factor for assessing modified flows at OHAEH 28_5. Geomorphologically this section of river is classified as Lower Foothill, and therefore has a comparatively gentle gradient, so it is unlikely that the macro-invertebrate fauna would comprise many taxa with a preference for very high current speeds..

The MIRAI index requires estimation of the expected and observed Frequency of Occurrence and is therefore applicable to a river reach rather than a specific site. In this study the assessment of PES in the Orange River was based on one sampling event at EFR O5, so it was not possible to determine an observed FROC other than using abundance as a surrogate for FROC.

7.7 Conclusions

The most important driver of the PES of macro-invertebrates in MRU Orange G is unnaturally elevated low flows. Other factors that are likely to have contributed to the modified state are aseasonal flows due to the operation of the system, increased cyanobacteria, increased nutrients, increased salinity, and possible competition from alien invasive species and reduction in woody snags. The frequency of high flow events that originate from the Fish River is a key driver of the composition and abundance of invertebrates in MRU Orange G. Low abundance of macro-invertebrates and scarcity of filter-feeders at EFR O5 in June 2012 is attributed to elevated turbidity following high flow in the Fish River at the end of March, two and a half months prior to sampling. A similar observation of very low abundance of macro-invertebrates was made near Sendelingsdrift in January 2004, when the only abundant taxon was the freshwater shrimp *Caradina sp.* (Family: Atyidae). During periods of high turbidity, autotrophic primary production is light-limited, and the production of heterotrophic microbes is presumably important in driving ecosystem processes. The macro-invertebrate composition in MRU Orange G are expected to tolerate periodic high flow events and associated elevated turbidity, and this is reflected by a dominance and relative abundance of Collector-Gatherers recorded in June 2012, including Oligochaeta, Atyidae, Baetidae and Chironomidae.

8. Fish

8.1 Background

Based on available information, twelve (12) indigenous freshwater fish species have previously been recorded in the lower Orange and Fish River System and its tributaries (excluding estuarine species) (Table 17). At least four alien or introduced fish species are known to occur in the lower Orange and Fish River system, while various other species have been kept at the Hardap Dam breeding facility from where some escaped from into the Fish River. There are also hybrids between the two yellowfish (*Labeobarbus aeneus* and *L. kimberleyensis*) and the two *Labeo* species (*Labeo capensis* and *L. umbratus*) known to be present in the Fish River system (Table 17).

Table 17. Fish species of the lower Orange and Fish River systems

Abbreviation	***Scientific names***
Native indigenous species	
ASCL	*Austroglanis sclateri* (Boulenger, 1901)
BAEN	*Labeobarbus aeneus* (Burchell, 1822)
BHOS	*Barbus hospes* (Barnard, 1938)
BKIM	*Labeobarbus kimberleyensis* (Gilchrist and Thompson, 1913)
BPAU	*Barbus paludinosus* (Peters, 1852)
BTRI	*Barbus trimaculatus* (Peters, 1852)
LCAP	*Labeo capensis* (Smith, 1841)
LUMB	*Labeo umbratus* (Smith, 1841)
CGAR	*Clarias gariepinus* (Burchell, 1822)
MBRE	*Mesobola brevianalis* (Boulenger, 1908)
PPHI	*Pseudocrenilabrus philander* (Weber, 1897)
TSPA	*Tilapia sparrmanii* Smith, 1840
Hybrids (Fish River)	
BKIM X BAEN (B. cf. KIM)	*Labeobarbus hybrid*
LCAP X LUMB	*Labeo hybrid*
Alien or introduced species	
CCAR	*Cyprinus carpio* Linnaeus, 1758
MSAL	*Micropterus salmoides*
OMOS	*Oreochromis mossambicus*
TREN	*Tilapia rendalli*

8.2 Fish of the lower Orange River

Selected aspects regarding the fish species and distribution of the lower Orange River, relevant to the current study, is summarised below in Table 18.

Table 18. Fish species and distribution of the lower Orange River

Fish sp.	***Comment***
Native indigenous species	
ASCL	Endemic to Orange-Vaal River system. Present throughout Orange System. Indicated as one of most threatened species in Orange River System. The International Union for Conservation of Nature (IUCN, 2007) rated least concern. SA Red Data Book (1987) rare (indeterminate).
BAEN	Naturally endemic to Orange-Vaal system. Translocated to other systems in South Africa.
BHOS	Endemic to Orange River System. Only present downstream of Augrabies falls. Anatomically *B. hospes* is more suited to strong swimming than any other small *Barbus* species in Southern Africa. IUCN (2007): Least concern (IUCN 1996 near threatened, SA Red Data book 1987 rare (indeterminate).
BKIM	Endemic to Orange-Vaal River system. IUCN (2007): Near Threatened. National Environmental Management: Biodiversity Act (NEMBA, 2004): Vulnerable
BPAU	Relatively common *Barbus* species in many of South African rivers. Abundant in especially middle and lower Orange River.
BTRI	Populations of BTRI in Orange River have distinct body pigmentation, suggesting that the Orange River population is genetically distinct (DWAF, 1996b). BTRI considered vulnerable, especially in Lower Vaal. Also concern about population in Fish River. Low abundance in lower Orange River. Historic records below and above Augrabies falls.
CGAR	Common and widespread occurring throughout Orange-Vaal system, and many other rivers in South Africa.
LCAP	Naturally endemic to Orange-Vaal system. Translocated to other systems in South Africa.
LUMB	Skelton and Cambray (1981): Very scarce during 1980 survey in middle and lower Orange. Described as not very successful lotic species (especially in face of competition with LCAP). Benade (1993): Traditionally widespread in Orange River system above Augrabies has become restricted to mainly upper Orange River dams. Probably flow regulation, and siltation of breeding habitats (egg smothering). LUMB has effectively disappeared below Vanderkloof Dam. Benade (1993) recommended that it be considered for inclusion as Red Data listed (threatened) for the Orange River System. Jubb (1967) indicates its distribution range in the Orange River as upstream of Augrabies falls. Some records in FROC database (Kleynhans and Louw, 2007) for this species below falls (possibility of colonization from Fish River?). Introduced indigenous OMOS may compete with LUMB in lower OR for food (detritus) and therefore be a possible contributing factor to their scarcity/absence.
MBRE	The Augrabies Falls form the upstream barrier of distribution range in Orange River. Unconfirmed records in Molopo River downstream of Mafikeng? (could be introduced).
PPHI	DWAF (1996b): Cichlids have become invasive between Boegoeberg and Augrabies. PPHI surprisingly common in a wide variety of habitats along the middle and lower Orange (Skelton and Cambray 1981; Cambray 1982). Gaige et al (1980) indicated no previous records in Orange River, only being present in Wondergat and Kuruman eye.
TSPA	DWAF (1996b): Cichlids have become invasive between Boegoeberg and Augrabies. TSPA was, in contrast to PPHI, rather scarce in middle/lower Orange River, suggesting the possibility of competitive exclusion by the aggressive haplochromine. TSPA of upper Molopo

Fish sp.	***Comment***
	River genetically and morphologically distinct from other known conspecific populations.
Alien and Indigenous Introduced Species	
OMOS	Introduced indigenous species (Benade, 1993). Present in lower Orange River only and unlikely to spread due to preference for warmer water (>22°C; Skelton, 1993). Present in Fish river and main stem below Vioolsdrift (Gaiger, 1975, Skelton and Cambray, 1981). IUCN (2007) - Near threatened due to hybridization. Augrabies falls fortunately barrier for further instream colonization, although cold should also be limiting factor. This species will compete with other naturally occurring indigenous fish species (especially in terms of food-diatoms, detritus and to some extent invertebrates) negatively impacting on the ecological integrity of the lower OR (may compete for food with LUMB – detritus).
CCAR	Alien (Europe and Asia).

8.3 Methodology

The Fish Response Assessment Index (FRAI) (Kleynhans, 2008) was applied to determine the present ecological status of MRUs represented by an EFR site. All available information on fish distribution in the Fish River was used, together with results gained during a fish survey conducted during June 2012.

The following must be noted in terms of the application of the FRAI on the Fish River:

- The FRAI was developed for perennial systems, and for application to river reach (not site). Certain aspects/metrics and rules were therefore altered for the application to the Fish River, which is classified as an ephemeral river with perennial pools.
- FROC values in FRAI generally based on the number of sites within a river reach (fish habitat segment) where a species can be expected/occur. For the purpose of the current study, the site/reach consisted of a stretch of the river that included different pools as well as their connections. Within the site/reach, various sub-sites were sampled. The FROC for a species was therefore calculated based on this information (i.e. proportion of sub-sites where species expected/occur):
    - 1=Present at very few sub-sites (<10% of sub-sites).
    - 2=Present at few sub-sites (>10-25%).
    - 3=Present at about >25-50 % of sub-sites.
    - 4=Present at most sub-sites (>50- 75%).
    - 5=Present at almost all sub-sites (>75%).

8.4 Fish reach delineation

According to the delineation of the study area (Technical Report 22) this site falls in MRU Orange G (Figure 1). The FRAI for site EFR O5 apply to the freshwater reach of the lower Orange River and excludes estuarine influences.

8.5 Results

Within the site/reach, various sub-sites were sampled which represented different habitats/biotopes present at the EFR site. A summary of the fish species sampled at each site during the June 2012 survey is provided in Appendix C. Detailed data regarding the June 2012 survey (raw data) is provided on the ORASECOM website (www.orasecom.org).

8.5.1 Reference conditions

Based on the available fish distribution data and expected habitat composition of the river reach of EFR O5, twelve indigenous fish species (ASCL, BAEN, BKIM, BHOS, BTRI, BPAU, MBRE, LCAP, LUMB, CGAR, PPHI and TSPA) have a high to definite probability of occurrence under reference conditions in this reach. The expected habitat composition at the site under reference conditions met the requirements of all these fish species. The expected spatial FROC of most species was relatively high, with the exceptions being ASCL and LUMB which is expected to have been scarce even under natural conditions (see Table 19) below for detailed rationale regarding reference condition of each species).

Table 19. Fish species expected under reference conditions at EFR O5

Species	***Comment***	***Reference FROC***
ASCL	Included as Code 3 species in reference FROC of site D8ORAN-SENDE, and recorded during current survey. Expected to naturally have a low FROC, although preferred habitats would have been abundant/common.	1
BAEN	All indications are that it was very abundant under natural conditions. Sampled at most sites in reach.	5
BHOS	Included in reference FROC of site D8ORAN-VIOO and previously records of this species at other sites in reach.	4
BKIM	FROC expected to be naturally low to moderate under reference condition due to status in food chain (predator).	3
BPAU	Thought to have been relatively abundant with high FROC under natural conditions. Previously recorded at many sites in reach.	4
BTRI	Known to occur both up- and downstream of Augrabies Falls. Sampled during current survey and various other sites and surveys in this reach.	4
CGAR	Common and widespread, not abundant and often not sampled.	4
LCAP	All indications are that it was very abundant under natural conditions.	5
LUMB	Very scarce during 1980 survey in middle and lower Orange. Described as not very successful lotic species (especially in face of competition with LCAP). Benade (1993): Traditionally widespread in Orange River system above Augrabies has become restricted to mainly upper Orange River dams. Probably flow regulation, and siltation of breeding habitats (egg smothering). LUMB has effectively disappeared below Vanderkloof Dam. Benade (1993) recommended that it be considered for inclusion as Red Data listed (threatened) for Orange River system. Due to the uncertainty regarding the natural occurrence of this species in the lower OR, it was included as very low FROC of 1.	1

Species	Comment	Reference FROC
MBRE	Described as one of most abundant species in lower Orange River. Sampled previously at many sites in reach. Expected to have had a naturally high FROC under reference conditions.	4
PPHI	DWAF (1996b): Cichlids have become invasive between Boegoeberg and Augrabies. Does this indicate possible invasion of lower Orange River as well? PPHI surprisingly common in a wide variety of habitats along the middle and lower Orange (Skelton and Cambray 1981; Cambray 1982). Gaiger *et al.* (1980) indicated no previous records in Orange River, only being present in Wondergat and Kuruman eye (this could have been due to sampling information being limited). It is therefore assumed that if this species did occur in this reach under reference conditions, it would have had a relatively high FROC.	4
TSPA	DWAF (1996b): Cichlids have become invasive between Boegoeberg and Augrabies. TSPA was, in contrast to PPHI, rather scarce in middle/lower Orange River, suggesting the possibility of competitive exclusion by the aggressive haplochromine. FROC reduced as this species most probably naturally lower abundance and FROC.	3

Refer to further detailed discussion on each species regarding the rational for inclusion/exclusion of fish species in this river reach (Technical Report 28 - Appendix D).

8.5.2 Present ecological state

Eleven of the expected twelve indigenous fish species were sampled in the reach during the June 2012 survey, together with one alien/introduced species (OMOS). The one species not sampled during the survey, namely LUMB, is still expected to occur in this reach in very low FROC. The abundance and spatial FROC of the indigenous species sampled were generally high for most species (LCAP > BAEN > MBRE > BPAU > BHOS), while ASCL, BKIM, CGAR, PPHI and TSPA were relatively scarce during the survey. Based on all considerations of impacts and available fish information, it was estimated that the present FROC of many species were comparable to reference condition, while a few had slightly reduced FROC (BKIM, BPAU, BTRI, LUMB, PPHI and TSPA). The primary impacts include modified flow regimes as well as water quality deterioration. Overall the fish assemblage was therefore estimated to currently still be in a largely natural to slightly modified state (PES=B/C – 79.9%). The expected change in FROC under present conditions is provided in Table 20.

Table 20. Fish species present under present conditions at EFR O5

Species	Comment	Present FROC*
ASCL	Sampled in very low abundance at site during 2012 survey, but thought to still be present in reach at FROC close to reference conditions (<10% FROC).	1
BAEN	Still abundant at site, and due to abundance of preferred habitats and relative good condition, this species is thought to be present in FROC similar to reference conditions.	5
BHOS	Sampled at relative high abundance during current survey which is an indication that this species may be favoured by the altered flow regime of the Orange River.	4

Species	***Comment***	***Present FROC****
BKIM	Sampled during 2012 but expected to occur at reduced FROC. This species as top predator and being moderately intolerant to changes in the environment is expected to be impacted negatively to some extent. Expected impacts will be related to changes in food sources (trophic), flow modification, water quality deterioration and potentially overall habitat deterioration. The optimal habitat of this species is however still abundant in this reach, and the species is therefore expected to still occur at relatively high FROC (compared to many other reaches of the Orange River). Impact due to increased turbidity (predatory species as adult).	2
BPAU	Sampled during 2012. Expected to be present in slightly reduced FROC due to change in marginal vegetation as cover. Loss of marginal vegetation results in reduced habitat and therefore abundance of this species (also feeding and breeding habitats).	3.5
BTRI	Relatively low abundance in reach during 2012 survey. Potentially impacted to some extent by reduced flows (loss of habitat, including overhanging vegetation).	2
CGAR	Sampled in 2012. Tolerant species expected to still be present in close to natural FROC. Potentially impacted by loss of deep habitats, as well as reduced floodplain-channel connectivity, and marginal vegetation (especially inundation for breeding purposes).	4
LCAP	Very abundant at site and expected to still occur at FROC, comparable to reference conditions. This species may have been favoured by increased nutrients, creating increased algal growth (food sources) for this species, together with the high abundance of its preferred habitats (fast flows over rocky substrates). This may however have resulted in higher abundance than under natural condition and may be negative for the overall biotic integrity, as domination by any species result in a shift in the natural equilibrium.	5
LUMB	Not sampled during 2012, but expected to still be present at reduced FROC. Though to be impacted by flow modification as this species has preference for slow habitats (lentic habitats rather than lotic habitats). Also potentially impacted by alien CCAR through competitive feeding in bottom substrates. Introduced indigenous OMOS may compete with LUMB in lower Orange River for food (detritus) and therefore be a possible contributing factor to their scarcity/absence.	0.5
MBRE	Abundant during 2012 survey. Expected to still occur at relatively high FROC, slightly reduced from natural. Possibly impacted by flow modification) loss of SD and SS habitat and water column for cover. Potentially also impacted by water quality deterioration (toxics and nutrients).	4
PPHI	Sampled during 2012. Thought to be relatively abundant with slight impact related to loss of marginal vegetation habitats.	3
TSPA	Sampled during 2012. Thought to be relatively abundant with slight impact related to loss of marginal vegetation habitats.	2

*FROC scoring:
: 1 = Present at very few sites (<10% of sites) 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%)

The FRAI results are provided in Table 21. The guidelines for rating/change are based on a score of -5 to 5 and provided below:

-5 = Extreme loss from reference (absent)

-4 = Serious loss from reference

-3 = Large loss from reference

-2 = Moderate loss from reference

-1 = Small loss from reference

0 = No change from reference

1 = Small increase from reference

2 = Moderate increase from reference

3 = Large increase from reference

4 = Serious increase from reference

5 = Extreme increase from reference (completely dominant)

Table 21. FRAI results for the EFR O5 reach

Metric	***Rating (change)***
Velocity-depth classes (Weight: 100%)	
Response of species with high to very high preference for fast-deep (FD) conditions.	-0.5
Response of species with high to very high preference for fast-shallow (FS) conditions.	-0.5
Response of species with high to very high preference for slow-deep (SD) conditions.	-0.5
Response of species with high to very high preference for slow-shallow (SS) conditions.	-0.5
Cover (Weight: 94%)	
Response of species with a very high to high preference for overhanging vegetation.	-1.5
Response of species with a very high to high preference for undercut banks and root wads.	-1.0
Response of species with a high to very high preference for a particular substrate type.	0.0
Response of species with a high to very high preference for instream vegetation.	-1.0
Response of species with a very high to high preference for the water column.	-0.5
Flow dependence (Weight: 82%)	
Response of species intolerant of no-flow conditions.	0.0
Response of species moderately intolerant of no-flow conditions.	0.0
Response of species moderately tolerant of no-flow conditions.	-1.0
Response of species tolerant of no-flow conditions.	-0.5
Physico-chemical (Weight: 47%)	
Response of species intolerant of modified physico-chemical conditions.	0.0
Response of species moderately intolerant of modified physico-chemical conditions.	-1.5
Response of species moderately tolerant of modified physico-chemical conditions.	0.0
Response of species tolerant of modified physico-chemical conditions.	-1.0
Migrations (Weight: 61%)	
Response in terms of distribution/abundance of spp. with catchment scale movements.	n/a
Response in terms of distribution/abundance of spp. with requirement for movement between reaches or fish habitat segments.	0.5
Response in terms of distribution/abundance of spp. with requirement for movement within reach or fish habitat segment.	1.0

Metric	***Rating (change)***
Introduced species (Weight: 51%)	
The impact/potential impact of introduced competing/predaceous spp.	1.0
How widespread (frequency of occurrence) are introduced competing/predaceous spp.?	1.0
The impact/potential impact of introduced habitat modifying spp.	2.0
How widespread (frequency of occurrence) are habitat modifying spp.?	2.0
FRAI Score (%)	79.9
FRAI Category	**B/C**
FRAI Category Description	Largely natural /Moderately modified

9. Habitat integrity of the Orange River

Habitat integrity refers to the maintenance of a balanced, integrated composition of physico-chemical and habitat characteristics (temporally and spatially) that are comparable to the natural riverine habitat characteristics (Kleynhans et al., 2009). The habitat integrity status for a river provides the template for a certain level of biotic integrity to be realised. Habitat integrity assessments can be seen as a precursor to biotic integrity assessments. Habitat and biotic integrity together constitute ecological integrity. Separate assessments of the instream and riparian habitat integrities are undertaken according to a number of key criteria. The observed habitat condition in terms of these criteria is compared to a perceived unperturbed condition to estimate the change in habitat integrity. A rating system, based on differing weights for each criterion (according to its perceived importance in determining habitat integrity), is used to assess the river's instream and riparian habitat integrities. The sum of these ratings is used to classify the instream and riparian zone facets according to a descriptive integrity category. The Instream Index of Habitat Integrity (IHI) and the Riparian Index of Habitat Integrity are based on the methods outlined in Kleynhans et al. (2009).

9.1 Data and information

The IHI determination used the following:

- Personal ground-based observations.
- Local knowledge.
- Hydrological assessments.
- Water quality assessments.
- Land covers assessments.
- Google Earth (high resolution).

The confidence ratings (0 - 5 with 5 being very high) in the above is high (4) due to the detailed ground-based observations and the high quality Google Earth imagery available for large sections of the study area. The only low confidence issue is the lack of hydrological information in terms of losses, tributary inflows and groundwater interaction.

9.2 Results

The IHI is assessed for the instream and riparian components. Each of these is assessed for various metrics (Table 22). These metrics are rated on a scale of 0–5 with 5 referring to critical changes from natural conditions and 0 implying no changes from natural. The results are provided as Ecological Categories of A (near natural) to F (critically modified).

The Instream and Riparian IHI results are summarised in Table 22 and 23.

Table 22. Instream IHI results

Instream IHI	***EFR O5***
Base flows	2.0
Zero flows	1.0
Floods	3.5
Hydrology rating	2.0
pH	0.5
Salts	2.0
Nutrients	1.5
Water temperature	1.0
Water clarity	1.0
Oxygen	0.5
Toxics	2.0
Physico-chemical rating	1.3
Sediment	2.0
Benthic growth	1.5
Bed rating	1.7
Marginal	2.0
Non-marginal	1.5
Bank rating	1.8
Longitudinal connectivity	2.0
Lateral connectivity	0.5
Connectivity rating	1.4
Instream IHI %	67
Instream IHI EC	C
Instream confidence	2.4

Table 23. Riparian IHI results

Riparian IHI	***EFR O5***
Base flows	1.0
Zero flows	0.0
Moderate floods	3.0
Large floods	3.0
Hydrology rating	1.9
Substrate exposure (marginal)	0.5
Substrate exposure (non-marginal)	1.0
Invasive alien vegetation (marginal)	0.5

Riparian IHI	***EFR O5***
Invasive alien vegetation (non-marginal)	1.0
Erosion (marginal)	0.5
Erosion (non-marginal)	1.0
Physico-chemical (marginal)	1.5
Physico-chemical (non-marginal)	0.0
Marginal	1.5
Non marginal	1.0
Bank structure rating	1.3
Longitudinal connectivity	0.0
Lateral connectivity	0.0
Connectivity rating	0.0
Riparian IHI %	76.2
Riparian IHI EC	C
Riparian confidence	4.2

9.3 Summary

The results are summarised in Table 24.

Table 24 Instream and riparian IHI summary

Instream IHI	***EFR O5***	***Riparian IHI***	***EFR O5***
Hydrology rating	2.0	Hydrology rating	1.9
Physico-chemical rating	1.3	Bank structure rating	1.3
Bed rating	1.7	Connectivity rating	0
Bank rating	1.8		
Connectivity rating	1.4		
Instream IHI %	67	Riparian IHI %	76.2
Instream IHI EC	C	Riparian IHI EC	C
Instream confidence	2.4	Riparian confidence	4.2

The key causes and sources of the C EC for the instream and riparian IHI are the operation of upstream dams, irrigation abstraction and return flows. Bank modification due to mining, roads, the camp site and goats also play a role.

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Appendix A Species lists

A.1 Riparian vegetation

The legend pertaining to species list for EFR O5 (Table A1) is provided below.

Invasive Alien

Weed[1] = weed classified as category 1 invader.

NE = naturalized exotic.

Endemic

SA = South Africa.

SnA = southern Africa.

Riparian Indicator

0 = terrestrial, but can be found in riparian zone/wetland/floodplain.

1 = preferential riparian species.

2 = upper zone riparian obligate/floodplain species/wetland obligate (temporary zone).

3 = lower zone riparian obligate/wetland obligate (seasonal zone)/hydrophyte.

4 = marginal zone riparian obligate/rheophyte/helophyte/hydrophyte/wetland obligate (permanent zone)/sudd hydrophyte (an aquatic plant that grows rooted in sudd, which generally is an impenetrable mass of floating vegetable matter).

5 = aquatic (epihydate, pleustophyte, vittate).

Wetland Obligate

E = Estuarine.

L = Lacustrine.

P = Palustrine.

R = Riverine and

0 = opportunistic wetland.

1 = facultative negative (<25%).

2 = facultative wetland (50%).

3 = facultative positive (67-99%).

4 = obligate wetland (>99%).

Table A1. Riparian vegetation species list for EFR O5

Species (52)	**Status**						
	Invasive alien	**Endemic**	**Aquatic**	**IUCN listing**	**Riparian indicator**	**Wetland obligate**	**Protected**
Acacia erioloba				Declining	1		y
Acacia karroo				LC	1		
Ageratum houstonianum	Cat 1			LC			
Amaryllis paradisicola		SA		VU	1		
Bolboschoenus glaucus				LC	4	P4	
Cotula coronopifolia			y	LC	4	y	
Cullen tomentosum				LC	1		
Cynodon dactylon				LC			
Cyperus laevigatus				LC	3	y	
Cyperus longus var. *longus*				LC	4	y	
Cyperus longus var. *tenuiflorus*				LC	4	y	
Cyperus marginatus				LC	4	y	
Datua innoxia	Cat 1			x			
Diospyros lycioides subsp. *lycioides*				LC	0		
Ectadium virgatum				NT	2		
Euclea pseudebenus		y		LC	1		y
Ficus cordata subsp. *cordata*				LC	1		
Fimbristylis bisumbellata				LC	3	y	
Gomphocarpus fruticosus subsp. *fruticosus*				LC	3	y	
Gomphostigma virgatum				LC	4		
Gymnosporia linearis subsp. *lanceolata*		SnA		LC	2		
Hemarthria altissima				LC	3	y	
Hoodia gordonii				DD	1		
Juncus punctorius				LC	4	y	
Kohautia cynanchica				LC	1		
Lebeckia linearifolia				LC	1		
Ludwigia octovalvis				LC	4	y	
Lycium bosciifolium				LC			
Lycium cinereum				LC			

Species (52)	***Status***						
	Invasive alien	***Endemic***	***Aquatic***	***IUCN listing***	***Riparian indicator***	***Wetland obligate***	***Protected***
Maerua gilgii				LC	2		
Maytenus linearis							
Nicotiana glaucea	weed [1]			x	0		
Nymania capensis		y		LC			
Olea europaea subsp. *africana*				LC	1		
Persicaria decipiens				LC	4	y	
Persicaria lapathifolia	y			x	4	y	
Phragmites australis				LC	4	y	
Potamogeton pectinatus			y	LC	5	y	
Potamogeton schweinfurthii			y	LC	5	y	
Prosopis glandulosa var. *glandulosa*	Cat 2			x	2		
Prosopis velutina	Cat 2			x	2		
Salix mucronata subsp. *mucronata*				LC	3		
Schoenoplectus scirpoides				LC	4	y	
Schotia afra var. *afra*		SA		LC	1		
Searsia lancea				LC	1		
Setaria incrassata				LC	2		
Sisyndite spartea				LC	2		
Stipagrostis ciliata var. *capensis*				LC	1		
Tamarix usneoides		y		LC	2		
Veronica anagallis-aquatica				LC	4	y	
Ziziphus mucronata subsp. *mucronata*				LC	1		
Zygophyllum simplex				LC	1		

A.2 Riverine fauna

The species list of the riverine fauna of the Orange and Fish river systems are provided in Appendix A, Technical Report 28.

Appendix B Riverine fauna habitat plan views

The river plan views linked to habitats are provided below.

Figure B1. EFR O5: Google Earth view of study area, Orange River

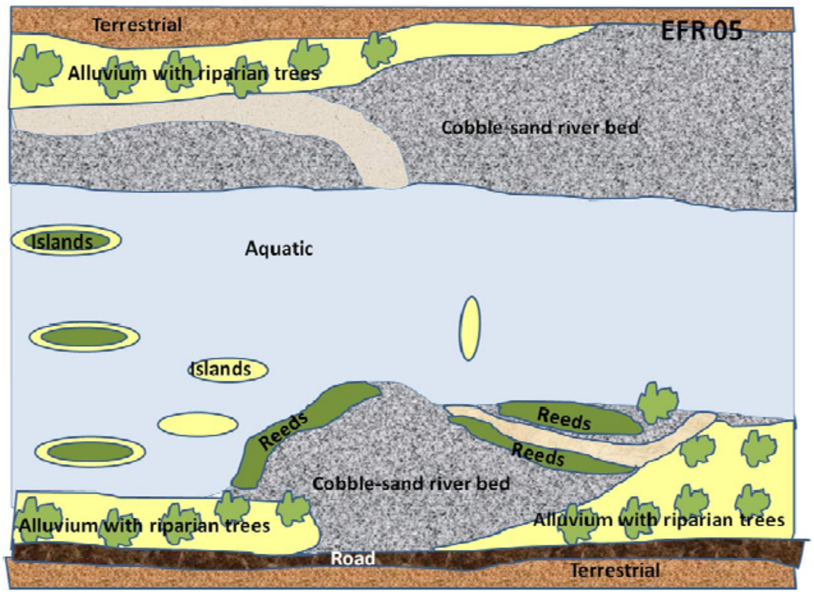

Figure B2. EFR O5: Schematic view of area

Figure B3–B7 illustrates the height of different habitats above or below the water level as experienced during the site visit. The purpose of the figures is to relate the impacts of the different scenarios to the change in habitats and was used during the scenario evaluation of the impact on riverine fauna (as presented in Technical Report 29).

In Figures B3–B7 water levels are represented by the yellow/blue line (centre of figures). The left side of the figures depict the different habitats that were available at EFR O5 during the survey. The right hand side of the figures show the general height of the different habitats below or above the water levels. Black semi-circles with arrows pointing to the right indicate habitat above the water level and corresponding distances in cm or m indicates the height above the water level. Arrows to the left indicate that the habitat was below the water level.

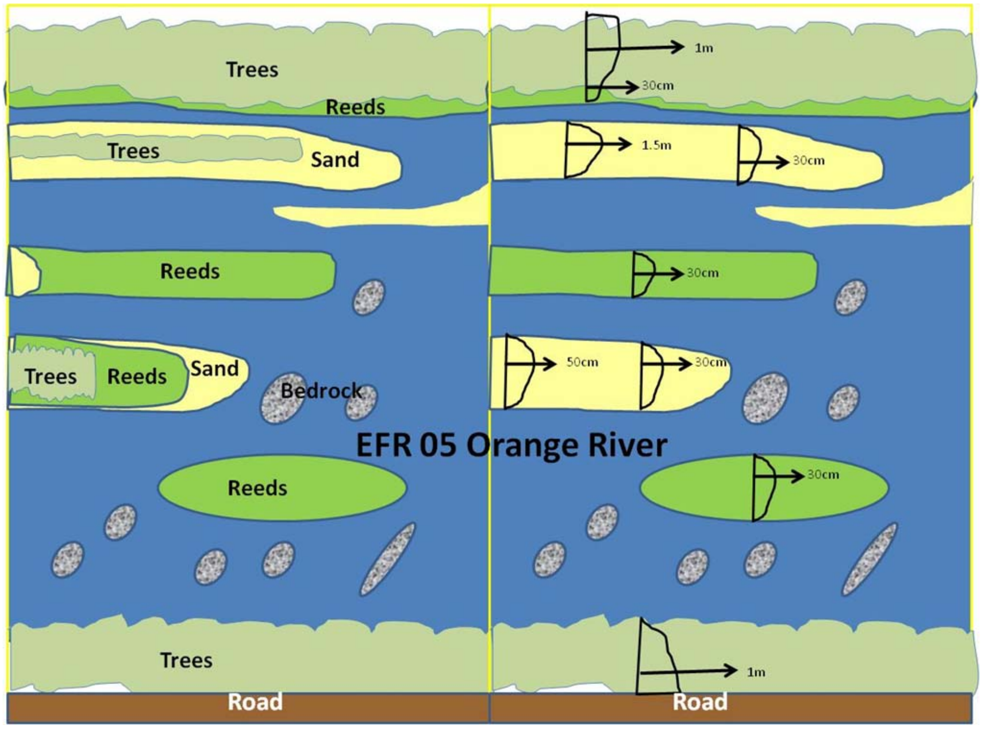

Figure B3. Transect 1: Habitat diversity and associated height above water level

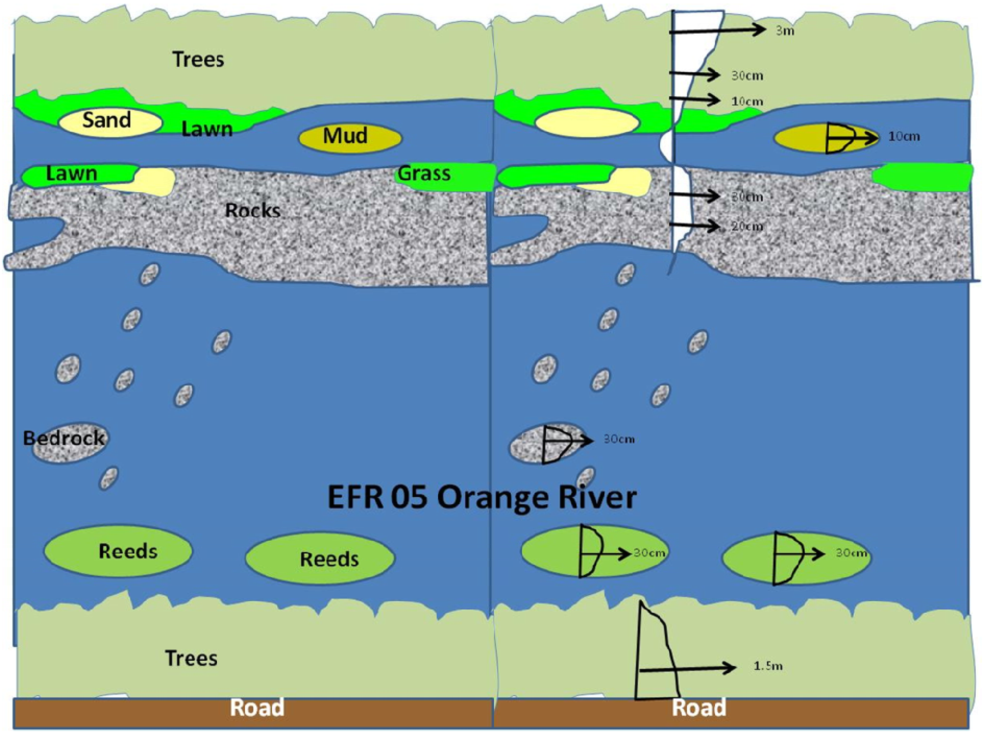

Figure B4. Transect 2: Habitat and associated height above water level

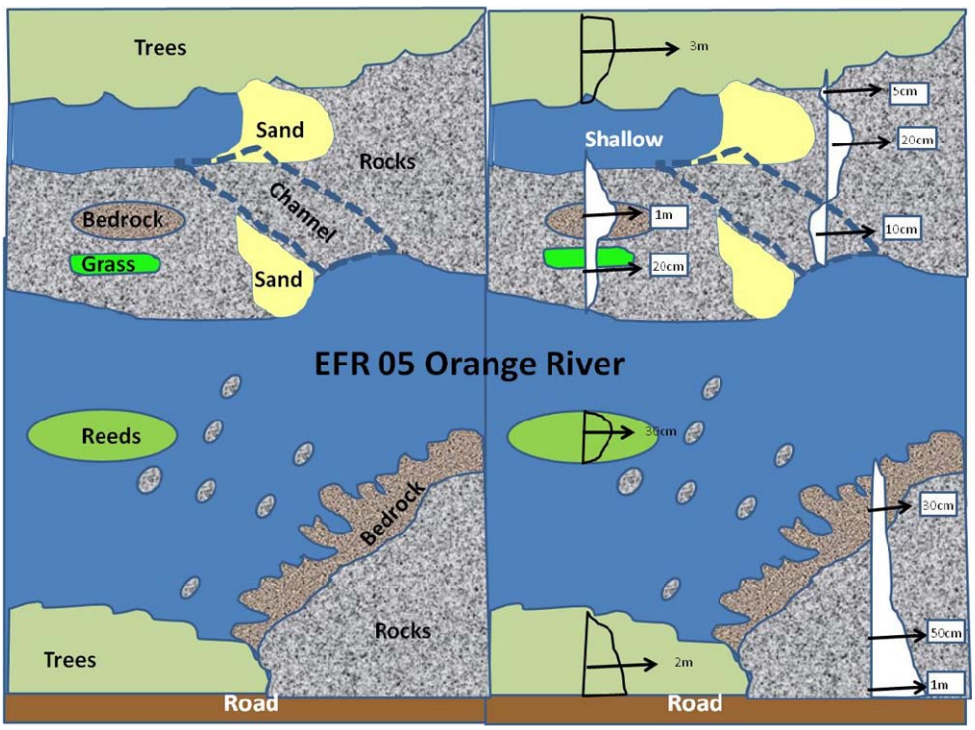

Figure B5. Transect 3: Habitat and associated height above water level

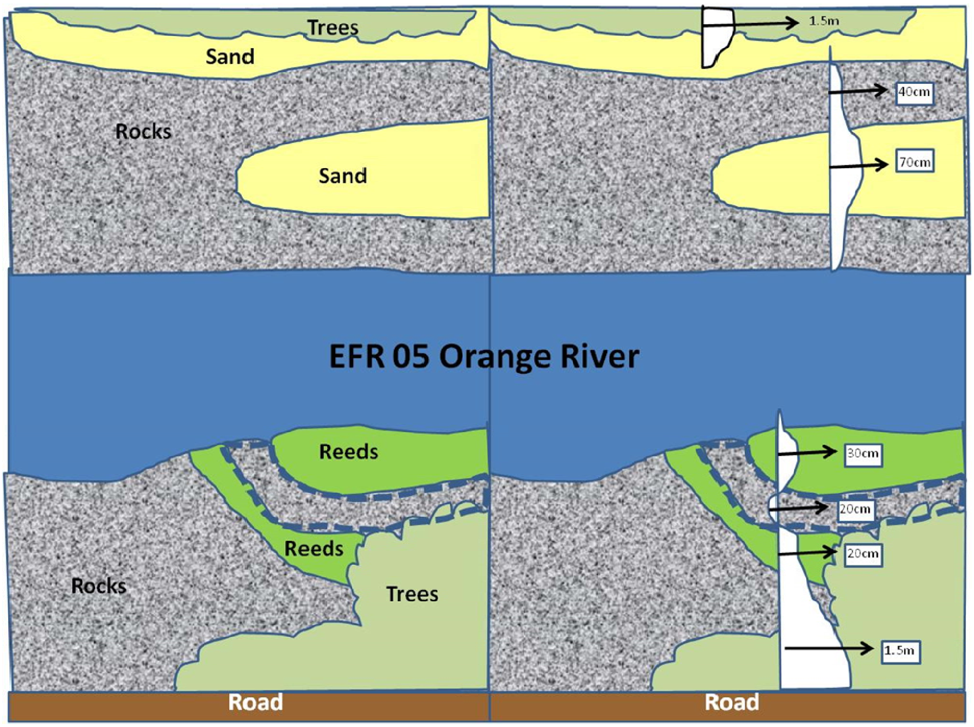

Figure B6. Transect 4: Habitat and associated height above water level

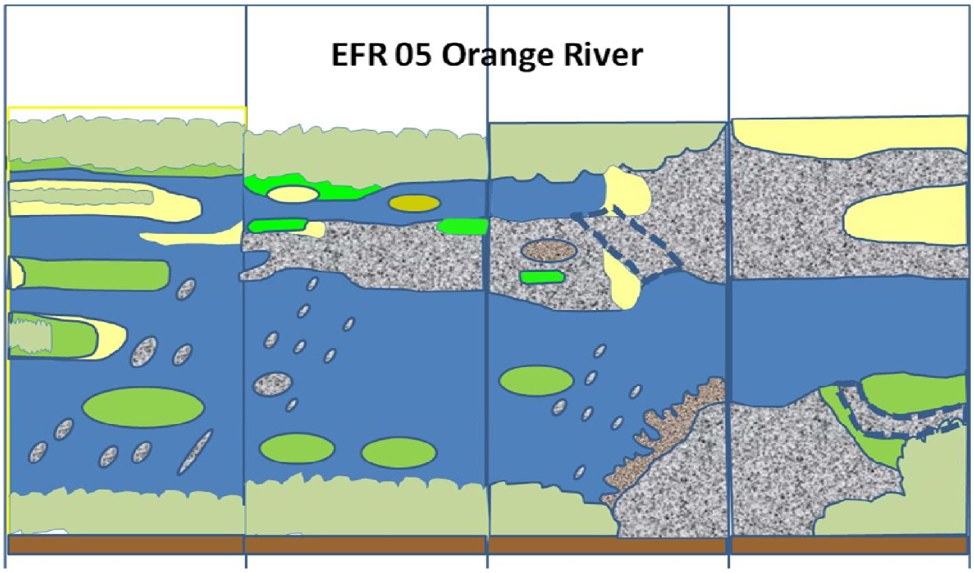

Figure B7. Composite map of riverine habitats at EFR O5

Appendix C Fish information used during the ecological classification process

Species present in the Orange River at the time of sampling were ACL, BAEN, BHOS, BKIM, BPAU, BTRI, CGAR, LCAP, MBRE PPHI, TSPA and the alien species OMOS.

The fish species differ in their preference for different velocity-depth categories and cover features. These preferences are shaded in grey in Table C1. They furthermore have different tolerance levels to changes in their environment (Table C2). These aspects play an important determining role in the fish assemblages expected under reference condition and present under current conditions at a site or river reach. This information was therefore used explicitly in determining reference conditions as well as in the interpretation of the present ecological state.

Table C1. Habitat preference of expected indigenous fish species in terms of velocity-depth categories and cover features (from Kleynhans, 2003)

Species	*SD*[1]	*SS*[2]	*FD*[3]	*FS*[4]	*Overhanging vegetation*	*Bank undercut*	*Substrate*	*Aquatic macrophytes*	*Water column*
ASCL	3.4	2.3	2.3	3.8	0.3	3.5	4.4	0.1	0.9
BAEN	3.5	2.5	3.5	4	0.7	1.5	4	2	4
BHOS	?	?	?	?	?	?	?	?	?
BKIM	3.7	2	4.3	3.8	0	0	1.8	0	3.3
BPAU	3.9	3.9	2.2	2.6	4.2	2.4	1.9	3.6	3.5
BTRI	3.9	3.2	2.3	2.7	3.9	2.6	2.3	2.8	2.8
CCAR	4.7	3.2	2.1	1.5	2.7	3	3	2.6	3
CGAR	4.3	3.4	1.2	0.8	2.8	2.9	2.8	3	2.6
LCAP	4.2	3	3.3	2.5	0.5	2	4.2	1.5	3.2
LUMB	4.5	2.7	1	0.9	0.6	0.1	4.2	0.8	2.5
MBRE	4.3	4.2	0.2	0.5	1.8	0.5	0.7	1	5
MSAL	4.5	3	0.8	0.8	3.1	3	3.1	3.2	1.7
OMOS	4.6	3.8	1.4	0.8	3	1.9	2.1	2.8	3.9
TSPA	3	4.3	0.9	1.5	4.5	1.9	2.5	3.6	1.1

1: <0.3 m/s; >0.5 m   2: <0.3 m/s; <0.5 m
3: (>0.3 m/s; >0.3 m   4: >0.3 m/s; <0.3 m

Habitat scores are outlined below:

0 = no preference, irrelevant

>0 - 0.9 = very low preference - coincidental?

>1 - 1.9 = low preference

>2 - 2.9 = moderate preference

>3 - 3.9 = high preference

>4 - 5 = very high preference

Table C2. Relative intolerance ratings of expected fish species in terms of various aspects (Kleynhans, 2003)

Species	***Trophic specialization***	***Habitat specialization***	***Flow requirement***	***Requirement: Unmodified water quality***	***Average overall intolerance rating***
ASCL	2.9	2.3	3.2	2.6	2.7
BAEN	2.5	1.8	3.3	2.5	2.5
BHOS					
BKIM	3.8	3.4	3.8	3.6	3.6
BPAU	1.6	1.4	2.3	1.8	1.8
BTRI	3.1	1.4	2.7	1.8	2.2
CCAR	1.2	1.4	2.1	1.1	1.4
CGAR	1	1.2	1.7	1	1.2
LCAP	3.4	3.1	3.5	2.8	3.2
LUMB	2.8	2	2.7	1.6	2.3
MBRE	3.1	2.2	1.1	2.8	2.3
MSAL	3.2	2	1.1	2.3	2.2
OMOS	1.2	1.9	0.9	1.3	1.3
TSPA	1.6	1.4	0.9	1.4	1.3

0 - 1.9 = Tolerant >2 - 2.9 = Moderately tolerant

>3 - 3.9 = Moderately intolerant >4 - 5.0 = Intolerant

? – Uncertain/Not available