Orange-Senqu River Basin

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

UNDP-GEF
Orange-Senqu Strategic Action Programme
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EFR Monitoring Programme

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

Technical Report 35
Rev 1, 30 October 2013

UNDP-GEF
Orange-Senqu Strategic Action Programme

EFR Monitoring Programme

Research Project on Environmental Flow Requirements of the Fish River and the Orange-Senqu River Mouth

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Revision	Description	Date	Signed
0	Consolidated first draft for internal review	29 Aug 2013	DL, LvN
1	Second draft including recommendations	30 Oct 2013	DL, LvN

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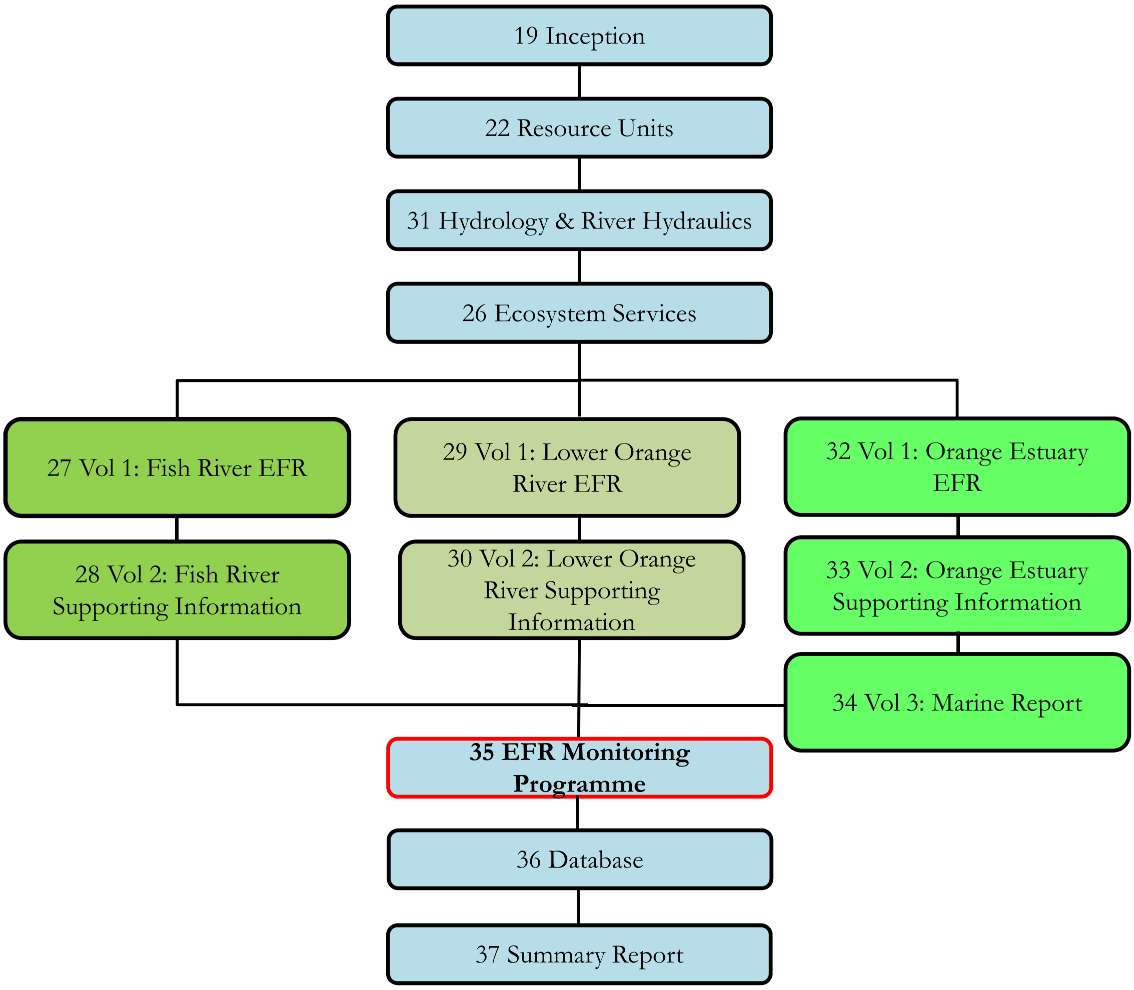
Report list

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-Senqu River Mouth

Technical Report No	Report
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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Executive summary

Introduction

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, 2011). Rivers for Africa was appointed to address the 'Research Project on Environmental Flow Requirements of the Fish River and the Orange-Senqu River Mouth'. The study area for this project is the Orange River downstream of the Fish River confluence (including the estuary and immediate marine environment) and the Fish River (Technical Report 22).

This report focuses on the proposed monitoring programme for the Fish and Orange rivers and the Orange Estuary. The objectives of this component of the project were to:

- set ecological specifications (EcoSpecs) and thresholds of potential concern (TPCs) for rivers and the estuary;
- provide a river monitoring programme;
- update the design of the existing Orange Estuary monitoring programme with the findings of this study.

Method

As part of the broader research project, environmental flow requirements (EFR) that would maintain the individual river reaches and estuary in particular ecological states, termed the ecological category (EC), were defined. Monitoring the ecological responses allows the predictions made during an EFR study to be tested.

Ecological water resources monitoring (EWRM) more specifically involves the measurement of EcoSpecs to determine whether the EC is attained (Kleynhans et al., 2009). EcoSpecs must be quantifiable, measurable, verifiable and enforceable, and ensure protection of all components of the resource that make up ecological integrity. In addition, TPCs are set as upper and lower levels of change for selected environmental indicators. These are used to prompt an assessment of the causes of the extent of change, which in turn provides the basis for deciding whether management actions are needed or if the TPC needs to be recalibrated.

EWRM should be undertaken within a structured framework following the principles of adaptive management. This will provide a decision framework within which monitoring results can be interpreted in terms of the attainment of objectives set for the condition and integrity of the resource. The design of a cost-effective monitoring programme for the rivers is based on different levels of monitoring.

- Level 1: Desktop approaches at a high frequency (e.g. annually).
- Level 2: Surveys and specialist analysis at low frequency (e.g. every 3 years).

Fish and Orange Rivers ecological specifications and thresholds of potential concern

The present ecological state (PES) and recommended ecological category (REC) determined at the different EFR sites provide the broad, qualitative EcoSpecs for each component (see tables below). The objectives to improve the PES to the REC are provided in the last column.

Since EFR Fish 1 is situated upstream of Neckartal Dam, it is in the ideal position to serve as a monitoring control site, providing operation of Hardap Dam does not change from the present. The purpose of the control site would be to aid in the interpretation of monitoring results obtained at EFR Fish 2 and in the determination of the causes and source of changes from the baseline. As this is a control site, only the PES is representative of the baseline.

EcoSpecs as ECs at EFR Fish 1 are provided in the table below.

Components	***PES***
Physico-chemical	C
Geomorphology	B/C
Fish	B
Macro-invertebrates	C
Instream	**B/C**
Riparian vegetation	B/C
Riverine fauna	B
EcoStatus	**B/C**

EcoSpecs as ECs at EFR Fish 2 are provided below.

Components	***PES***	***REC***	***Objectives to achieve the REC***
Physico-chemical	C	C	
Geomorphology	B/C	B/C	No improvement necessary as the floods cannot be provided.
Fish	B	B	Already in a B PES; no improvement required.
Macro-invertebrates	B	B	Already in a B PES; no improvement required.
Instream	**B**	**B**	Already in a B PES; no improvement required.
Riparian vegetation	C	C+[1]	The floods cannot be provided. The only issue that can be addressed is non-flow related, i.e. addressing the overgrazing by goats. This would only improve the vegetation within the C category
Riverine fauna	B	B	Already in a B PES; no improvement required.
EcoStatus	**C**	**C+**	**The only improvement that can be made within the EcoStatus category is non-flow related, i.e. controlling grazing (goats) and only relevant for riparian vegetation. All other EcoSpecs therefore will describe the ECs for the PES.**

The EcoSpecs as ecological categories at EFR O5 are provided below.

Components	***PES***	***REC***	***Objectives to achieve the REC***
Physico-chemical	C	C	
Geomorphology	B/C	B	
Fish	B/C	B	Improve wet season baseflow and reinstate droughts.
Macro-invertebrates	B/C	B	Improve wet season baseflow and reinstate droughts.
Instream	**B/C**	**B**	Improve wet season baseflow and reinstate droughts.
Riparian vegetation	B/C	B	Improve wet season baseflow, control alien vegetation and grazing.
Riverine fauna	B	B	Already in a B PES; no improvement required
EcoStatus	**B/C**	**B**	**The key improvement is flow-related, i.e. improving the wet season baseflows and reinstating droughts. Water quality improvements required for the estuary will have a positive effect on the river. Control of alien vegetation and grazing, although difficult, will also benefit the river.**

Within the report, quantitative (frequency and timing) and measurable EcoSpecs and TPCs are provided for the PES for various components (e.g. geomorphology, water quality, riparian vegetation, fish and macro-invertebrates), and their respective indicator species, guilds or habitats. These were based on the baseline survey undertaken mainly during June 2012.

Monitoring programmes

Fish River level 1 and 2

The monitoring programmes are summarised in the following tables.

Level 1 monitoring programme

Indicator	***Monitoring action***	***Temporal scale (frequency and timing)***	***Spatial scale***
Geomorphology			
Presence of pools	Map the area of full pools either by using aerial, Google Earth, satellite imagery or with handheld GPS on site (see detail actions required below the table).	Annually: Nov or Dec.	EFR Fish 1 EFR Fish 2
Water quality and diatoms (described in chapter 5)			
Salinity/dissolved oxygen/temperature	Install loggers in pools that will measure these variables. Collect data.	Continuous. Collect data for analysis every month.	EFR Fish 1 EFR Fish 2 New site: EFR Fish Ai-Ais
All variables measured as part of the ESIA[1]	Existing monitoring to be continued (assumption).	Three monthly.	Existing sites[2]: SW1, SW2, SW3, SW4

Indicator	*Monitoring action*	*Temporal scale (frequency and timing)*	*Spatial scale*
			New site: EFR Fish Ai-Ais
If the ESIA programme is discontinued, the alternative is the following:			
pH, Electrical Conductivity, nitrate-N, nitrite-N, ammonium-N, phosphate-P, metal ICP (inductively coupled plasma) spectrometric scan	Measure water quality variables.	Three monthly.	Existing sites[2]: SW1, SW2, SW3, SW4 New site: EFR Fish Ai-Ais
Diatoms	Field work linked to water quality measurements.	Six monthly.	EFR Fish 1 EFR Fish 2 EFR Fish Ai-Ais
Riparian vegetation			
Woody vegetation	Aerial photograph. Fixed point photos (linked to alternative geomorphological monitoring which requires a site visit).	Annually.	EFR Fish 1 EFR Fish 2
Reeds	Aerial photograph Fixed point photos (linked to alternative geomorphological monitoring which requires a site visit).	Annually.	EFR Fish 1 EFR Fish 2
Alien vegetation	Aerial photograph. Fixed point photos (linked to alternative geomorphological monitoring which requires a site visit).	Annually.	EFR Fish 1 EFR Fish 2
Macro-invertebrates			
Gomphid larvae	Visual assessment (see Appendix B) for use by regulatory agencies.	Annually.	EFR Fish 2

1 Environmental and social impact assessment undertaken for Neckartal Dam
2 Existing water quality site names: See Technical Report 28 for map and description of water quality measuring sites.

Level 2 Monitoring Programme

Indicator	*Monitoring action*	*Temporal scale (frequency and timing)*	*Spatial scale*
Geomorphology			
Size and depth of pools	Resurvey of hydraulic cross-sections.	5–10 years (low priority).	EFR Fish 1 EFR Fish 2
Riparian vegetation			
Woody vegetation	Fixed point photos, field assessments.	Every three years.	EFR Fish 2
Reeds	Fixed point photos, field assessments.	Every three years.	EFR Fish 2

Indicator	*Monitoring action*	*Temporal scale (frequency and timing)*	*Spatial scale*
Alien vegetation	Fixed point photos, field assessments.	Every three years.	EFR Fish 2
Population structure	Field assessment.	Every three years.	EFR Fish 2
Fish			
Labeobarbus aeneus, *L. kimberleyensis*, *Labeo capensis*, *L. umbratus*, *Clarias gariepinus*, *Barbus paludinosus*, and *Oreochromis mossambicus*	Field assessment (electrofishing).	Every three years, dry season (same month as baseline).	EFR Fish 2 (key) EFR Fish 1 EFR Fish Ai-Ais
Macro-invertebrates			
Composition and abundance	Field assessment (NASS2[1]) (low priority).	Every three years. Within three months of a high flow event.	EFR Fish 2

1 Namibian Scoring System version 2.

Orange River level 1 and 2

The monitoring programmes are summarised in the following tables.

Level 1 monitoring (water quality and diatoms) programme

Indicator	*Monitoring action*	*Temporal scale (frequency and timing)*	*Spatial scale*
All variables measured as standard by DWA[1].	Improve frequency and include in formal monitoring programme.	Monthly, or determined by monitoring programme.	D8H012Q01 gauging weir
All variables measured as standard by DWA as well variable for RHP[2]	Install additional logger for RHP.	Continuous.	At the new DWA gauge at Sendelingsdrift
Diatoms	Field work (recommendation to incorporate park rangers to collect data).	Six monthly.	EFR O5

1 Department Water Affairs, South Africa.
2 River Health Programme.

Level 2 monitoring programme

Indicator	*Monitoring action*	*Temporal scale (frequency and timing)*	*Spatial scale*
Geomorphology			
Channel pattern (planform) (low priority)	Assessment of aerial photographs or high resolution satellite imagery.	Every five years.	EFR O5
Active channel size (very low priority)	Resurvey of the hydraulic cross-sections at each EFR site.	When triggered by other indicators.	EFR O5

Indicator	*Monitoring action*	*Temporal scale (frequency and timing)*	*Spatial scale*
Riparian vegetation			
Woody vegetation	Field assessments.	Every three years.	EFR O5
Reeds	Field assessments.	Every three years.	EFR O5
Alien vegetation	Field assessments.	Every three years.	EFR O5
Sedges	Field assessments.	Every three years.	EFR O5
Population structure	Field assessment.	Every three years.	EFR O5
Fish			
L. aeneus, *L. kimberleyensis*, *L. capensis*, *L. umbratus*, *C. gariepinus*, *B. paludinosus*, *Austroglanis sclateri*, *B. hospes*, *B. trimaculatus*, *Mesobola brevianalis*, *Pseudocrenilabrus philander*, *O. mossambicus*, and *Tilapia sparrmanii*	Field assessment (electrofishing).	Every three years (dry season, same as baseline).	EFR O5 and other sites in MRU[1]
Macro-invertebrates			
Composition and abundance	Field assessment (SASS5[2]) (high priority).	Every three years.	EFR O5

1 Management resource unit.
2 South African Scoring System version 5.

Orange Estuary ecological specifications and thresholds of potential concern

The EcoSpecs and TPCs for the Orange Estuary are based on a REC of a C to meet Ramsar criteria and protected area status requirements. The broad, qualitative EcoSpecs for the Orange Estuary are shown below.

EcoSpecs as ecological categories at Orange Estuary

Components	**PES**	**REC**	**Objectives to achieve the REC**
Hydrology	D	D	Decrease baseflows in winter (reinstate droughts).
Hydrodynamics	C	B	Facilitate mouth closure in winter two to four times in 10 years.
Water quality	D	C	Reduce nutrient input in lower Orange River.
Physical habitat	**B**	**B**	Already in a B PES; no improvement required.
Microalgae	E	D	Reduce base flows in winter and decrease nutrient input.
Macrophytes	D	C	Reduce soil salinities, reduce nutrient input, remove cause way, control grazing and alien vegetation.
Invertebrates	D	B	Reduce baseflows in winter and facilitate mouth closure.
Fish	D	C	Reduce baseflows in winter and facilitate mouth closure, control fishing.
Birds	E	D	Reduce baseflows in winter and facilitate mouth closure.
EcoStatus	**D**	**C**	**Reduce flows, facilitate mouth closure, improve vegetation cover and food sources (invertebrates and fish).**

Orange Estuary monitoring programme

The monitoring programme is summarised below.

Indicator	*Monitoring action*	*Temporal scale*	*Spatial scale*
Hydrology	Measure freshwater inflow into the estuary.	Continuous.	Vioolsdrift (D8H003) and Brand Kaross
Hydrodynamics	Record water levels in the estuary.	Continuous.	At bridge and mouth
Hydrodynamics	Aerial/satellite photographs of estuary (preferably on spring low tide).	Every three years.	Entire estuary up to Brand Kaross
Sediment dynamics	Bathymetric surveys, sediment grab samples.	Every three years.	Entire estuary
Water quality	Conductivity, temperature, turbidity, dissolved oxygen, pH, inorganic nutrients and organic content.	Monthly continuous.	At river inflow
	Longitudinal salinity and temperature profiles.	Seasonally, every year.	Entire estuary
	Longitudinal water quality measurements of system variables and inorganic nutrients.	Seasonal surveys, every three years.	Entire estuary
Microalgae	Phytoplankton: Water column chl-a measurements.	Survey during normal flows.	Entire estuary
	Benthic microalgae: Intertidal and subtidal benthic chl-a measurements.		
Macrophytes	Survey main channel to assess status of macroalgae and submerged macrophytes. Ground-truthed vegetation maps. Assess extent of invasive species. Record plant cover, sediment salinity and sediment moisture content at three transects. Depth to water table and ground water salinity in supratidal marsh.	Summer survey every three years.	Entire estuary
Invertebrates	Record species and abundance of zooplankton and benthic invertebrate species.	Summer and winter survey every three years.	Entire estuary
Fish	Record species, abundance and size composition of fish, based on seine-net and gill net sampling.	Summer and winter survey every three years.	Entire estuary
Birds	Full count of all water-associated birds, covering as much of the estuarine area as possible, from a boat and on foot (this is also part of the requirements of Ramsar).	Summer and winter survey every year.	Entire estuary

Recommendations

Additional work to improve the baseline survey information is summarised in the table below.

Component	***Baseline survey***	***Temporal scale***
Rivers		
Water quality	EFR Fish 1 and EFR Fish 2: Additional salinity, dissolved oxygen and temperature measurements to be added to baseline (prior to Neckartal Dam construction). EFR Ai-Ais (new quality site): All water quality measurements.	Continuous
Diatoms	EFR Fish 2: Diatom collection (linked to water quality measurements prior to Neckartal Dam construction).	At least two dry season and wet season sampling.
Fish	All Fish River sites: Electrofishing.	One dry season survey
Estuary		
Hydrology	Determine what the actual discharge was to correlate with historical mouth closure.	1993 – 1996
Hydrodynamics and macrophytes	Lidar survey up to the 5 m mean sea level (MSL) contour.	Any time
Sediments	Sediment core samples along the entire estuary (10–20 m deep).	Once off
	Sample suspended sediment load at Vioolsdrift.	Daily
Invertebrates	Survey to account for the seasons and recruitment.	Seasonal (i.e. quarterly)
Fish	Survey to account for the seasons. Possible additional surveys in surf-zone required.	Seasonal (i.e. quarterly)

Specific monitoring studies

Specific studies required for better understanding of current issues are:

- Fish River nutrient assessment programme;
- estuarine nutrient assessment programme;
- toxin verification programme in the Orange Estuary;
- metals verification programme in the rivers.

General monitoring recommendations

- The use of the mini-SASS monitoring tool is recommended for more frequent (annual) assessment of conditions in the lower Orange River.
- Water quality loggers should be installed at the new Sendelingsdrift gauging weir to measure temperature, pH, electrical conductivity and dissolved oxygen.

- The monitoring programme should be initiated as soon as possible to avoid needing to redo the baseline and set new EcoSpecs and TPCs if the baseline (PES) changes.

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Abbreviations

ASPT	*Average score per taxon*
CEV	*Chronic effect value*
CWAC	*Co-ordinated Waterbird Counts*
DIN	*Dissolved inorganic nitrogen*
DO	*Dissolved oxygen*
DRP	*Dissolved reactive phosphorus*
DSS	*Decision support system*
DWA	*Department Water Affairs*
EC	*Ecological category*
EcoSpecs	*Ecological specifications*
EFR	*Environmental flow requirement*
EIS	*Ecological importance and sensitivity*
ESIA	*Environmental and social impact assessment*
EWRM	*Ecological water resources monitoring*
FRAI	*Fish Response Assessment Index*
FROC	*Frequency of occurrence*
ICP	*Inductively coupled plasma*
indiv/min	*individuals per minute*
IWRM	*Integrated water resources management*
MCB	*Macro channel bank*
MIRAI	*Macro Invertebrate Response Assessment Index*
MRU	*Management resource unit*
MSL	*Mean sea level*
NASS2	*Namibian Scoring System version 2*
NWA	*National Water Act*
ORASECOM	*Orange-Senqu River Commission*
PES	*Present ecological state*
REC	*Recommended ecological category*
RHP	*River Health Programme*
SAEON	*South African Environmental Observation Network*
SASS5	*South African Scoring System version 5*
SPI	*Specific Pollution sensitivity Index*
TDI	*Trophic Diatom Index*

TEACHA	*Tool for Ecological Aquatic Chemical Habitat Assessment*
TIN	*Total inorganic nitrogen*
TPC	*Threshold of potential concern*
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*
BPAU	*Barbus paludinosus*
BTRI	*Barbus trimaculatus*
CGAR	*Clarias gariepinus*
LCAP	*Labeo capensis*
LUMB	*Labeo umbratus*
MBRE	*Mesobola brevianalis*
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 strategic action plan for the management and development of water resources, based on Integrated Water Resources Management (IWRM) principles (ORASECOM, 2011).

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 a previous study conducted during 2009 – 2010. This area is to be the subject of this Research Project (Technical Report 22).

This report focuses on the proposed monitoring programme for the Fish and Orange rivers and the Orange Estuary.

1.2 Links with existing monitoring programmes

1.2.1 Orange River

In South Africa, the National Water Act (NWA, Act No. 36 of 1998) requires the establishment of a national monitoring system that must provide for the collection of appropriate data and information necessary to assess water resources. Such a system must ensure the collection of relevant information that contributes to the management of the resource in a desirable ecological condition. This monitoring programme will support these requirements. Previous long-term monitoring programmes for the Orange River as well as other rivers in South Africa has generally been unsuccessful due to the detail required and associated cost.

During 2010 the ORASECOM Secretariat proposed a single basin wide Orange-Senqu Joint Baseline Survey to be undertaken, which would provide a broad understanding of the state of the aquatic ecosystem at river sites throughout the basin using a range of ecosystem health monitoring protocols, and following the methodologies proposed in the Manual for Aquatic Ecosystem Health Monitoring for ORASECOM (ORASECOM, 2009). The outcome of this process would be an agreed detailed sampling programme which will form part of the overall Senqu Joint Baseline Survey programme, developed by the JBS-monitoring programme coordinator. The Orange-Senqu Joint Baseline Survey had three main components:

- Aquatic ecosystem health: Included a detailed assessment of all components of aquatic ecosystem health, as well as the impacts on aquatic ecosystems.
- Persistent organic pesticides and metals: Includes analyses of both the water and sediment fractions.
- An inter-laboratory calibration exercise: The intention of this programme was to support laboratories in each of the Member States with respect to improving and standardizing methodologies in each of the Member States.

1.2.2 Fish River

Knight Piésold initiated surface water and groundwater quality monitoring in the Neckartal project area to establish baseline conditions prior to the onset of construction of Neckartal Dam. Sites upstream and downstream of the dam were monitored, as well as a site downstream of the Naute Dam in the Löwen River. Four surface water sites were sampled bi-monthly and analysed for basic parameters to obtain an overview of water quality. On a bi-annual basis, a more detailed analysis was carried out. The Namibia Ministry of Water Affairs and Forestry – Keetmanshoop is currently managing the monitoring programme and the associated database. Monitoring has been is on-going and has been undertaken (Amelia Briel, pers. comm.).

1.2.3 Estuary

Existing Estuary monitoring programmes:

- Department of Agriculture, Fisheries and Forestry surveys the estuarine fish in the Orange Estuary every five years for two years in summer in winter.
- South African Environmental Observation Network (SAEON), Arid Node, has since 2011 undertaken annual surveys of the saltmarshes on the South African side of the estuary to monitor condition.
- Co-ordinated Waterbird Counts (CWAC) (hosted by the Animal Demography Unit, University of Cape Town) use to have bi-annual counts in this system. The relevant local authorities are in the process of reinstating these counts.

1.3 Study area

The study area is the Orange River downstream of the Fish River confluence (including the estuary and immediate marine environment) and the Fish River (Technical Report 22).

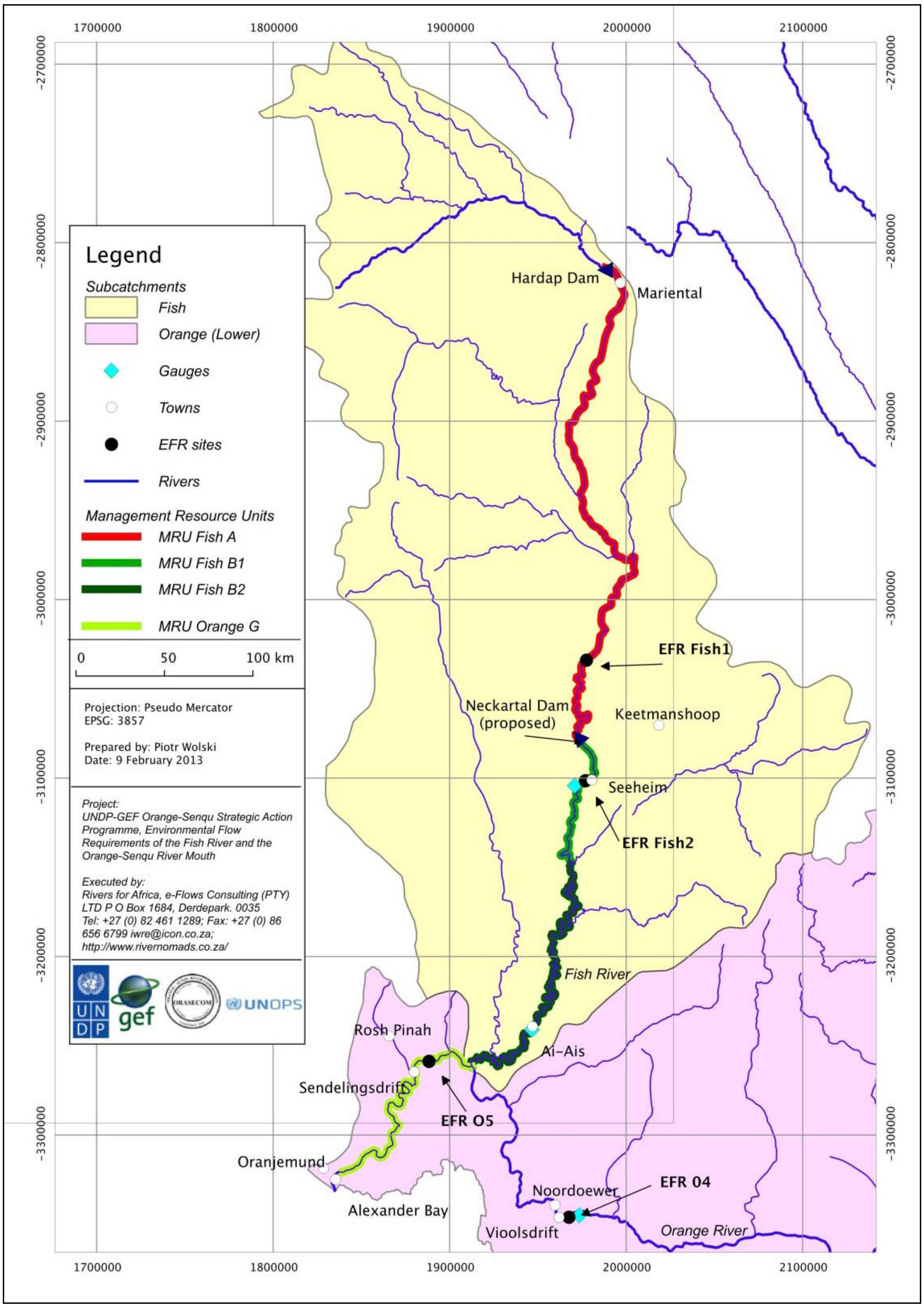

Figure 1. The study area

1.4 Objectives of the monitoring programme

A monitoring programme must be designed according to the principles of adaptive management to provide guidance on how to address issues if the ecological specifications (EcoSpecs) and thresholds of potential concern (TPCs) (Rogers and Bestbier, 1997) are exceeded.

The broad objectives of monitoring are to:

- set EcoSpecs and TPCs for rivers and the estuary;
- provide a river monitoring programme;
- update the existing Orange Estuary monitoring programme with the findings of this study.

1.5 Report structure

The report consists of the following chapters:

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

Chapter 2: Monitoring, ecological specifications and thresholds of potential concern
This chapter provides general background to the development and refinement of resource monitoring within the environmental flow requirement framework. Information is provided on ecological monitoring, EcoSpecs and TPCs, levels of monitoring and relevant terminology. The approach and application of this monitoring to the Fish River and lower Orange River system is also discussed

Chapter 3: Fish River: Ecological specifications and thresholds of potential concern
This section describes the metrics and indicators for EcoSpecs and TPCs for the different EFR components of the Fish River.

Chapter 4: Fish River: Level 1 monitoring programme
Level 1 monitoring refers to monitoring that is undertaken at a rapid or desktop level and could include a visual assessment undertaken by non-specialists. Level 1 monitoring as proposed in this chapter is specific to ephemeral rivers such as the Fish River due to the highly variable flow conditions that can be experienced and discussed in detail in this chapter.

Chapter 5: Fish River: Level 2 monitoring programme
Level 2 monitoring refers to detailed monitoring activities that require biophysical surveys at a frequency longer than the level 1 monitoring. The monitoring programme is summarised and additional supporting information on methods for data collection and data analysis is also supplied.

Chapter 6: Orange River: Ecological specifications and thresholds of potential concern
This section describes the metrics and indicators for EcoSpecs and TPCs for the different EFR components of the Orange River.

Chapter 7: Orange River: Level 1 monitoring programme
Level 1 monitoring for the Orange River is outlined in this section. As the river is currently a perennial river, the level 1 monitoring focuses only on water quality and diatom monitoring. This is different from the Fish River where the focus is on pools due to the ephemeral nature of the river

Chapter 8: Orange River: Level 2 monitoring programme
This chapter provides detailed monitoring activities required at a frequency longer than the level 1 monitoring. The monitoring programme is summarised and additional supporting information on methods for data collection and data analysis is also supplied.

Chapter 9: Orange River Estuary: Ecological specifications and thresholds of potential concern
This chapter describes the measures and indicators for EcoSpecs and TPCs for the different EFR components of the Orange Estuary.

Chapter 10: Orange River Estuary: Monitoring programme
This section provides the detailed baseline and long-term monitoring activities required to improve the overall confidence of future flow requirement studies. Results stemming from the proposed monitoring programme will also provide feedback on incremental health improvements achieved through the implantation of non-flow related interventions (e.g. removal of causeway).

Chapter 11: Recommendations
The existing baseline for the Fish and Orange rivers is summarised in this Chapter and the additional work required to improve the confidence in the baseline is also provided. Additional studies (once-off) that are required to address identified gaps in the understanding of the system functioning is provided and research recommendations are outlined.

Chapter 12: References

Appendix A: Visual assessment of the Fish River condition
The practical application of the proposed visual assessment of the river condition of the Fish River is explored in this Appendix. A data sheet, photo guide and general guidelines are provided.

2. Monitoring, ecological specifications and thresholds of potential concern

This chapter is modified from DWAF (2009) and DWA (2010).

2.1 Ecological monitoring

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

- the reference condition which is the natural or unimpaired condition of the system;
- the monitoring baseline which is a series of measurements taken before the initiation of the impact or management activity and used for comparison with the series of measurements taken afterward;
- response monitoring occurs at a particular detail, frequency and intensity as guided by the ecological importance and sensitivity (EIS) of the resource. Response monitoring results are evaluated by analysis within a management objective framework. This allows measurement of how the resource is changing over time, i.e. to measure the trend;
- implementation monitoring assesses whether the activities are carried out as designed. Implementation monitoring can also identify which variables are most likely to be causing a change in the resource, and help eliminate from consideration some potential causes of change (Kershner, 1997; Elzinga et al., 1998). This would, inter alia, refer to whether flows are released as was specified for the attainment of a particular EC;
- effectiveness monitoring measures whether the EC (in terms of EcoSpecs) are attained by following the particular management scenario (Kershner, 1997).

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

EWRM should be undertaken within a structured framework following the principles of adaptive management. This will provide a decision framework within which monitoring results can be interpreted in terms of the attainment of objectives set for the condition and integrity of the resource. This relates directly to EcoSpecs and TPCs (Rogers and Bestbier, 1997) formulated to assess attainment of an EC. Conclusions emanating from the DSS will provide guidance on the management of the resource (Cormier and Suter, 2008).

2.2 EcoSpecs and thresholds of potential concern

2.2.1 EcoSpecs

EcoSpecs must be quantifiable, measurable, verifiable and enforceable to ensure protection of all components of the resource, which make up ecological integrity. The critical components of the EcoSpecs include:

- requirements for water quantity. Flow requirements for a river reach, estuary, and/or water level requirements for standing water or ground water are included. Groundwater level requirements to maintain spring and baseflow in rivers and other ecological features are also considered;
- biological criteria and habitat criteria that are derived from EcoSpecs are clear and measurable specifications of ecological attributes (flow, physico-chemical attributes and biological integrity that reflect the health, community structure and distribution of aquatic biota).

EcoSpecs therefore define the EC.

2.2.2 Thresholds of potential concern

TPCs are upper and lower levels along a continuum of change in selected environmental indicators and are used and interpreted according to the following guidelines (Rogers and Bestbier, 1997): 'When a TPC level is reached (or when modelling predicts it will be reached), it prompts an assessment of the causes of the extent of the change. Assessment of the causes provides the basis for deciding whether management actions are needed or if the TPC needs to be recalibrated. TPCs provide management with strategic goals or endpoints within which to manage the system'.

'TPCs form the basis of an inductive approach to adaptive management, and are invariably hypotheses of limits of acceptable change in ecosystem structure, function and composition. The validity and appropriateness of TPCs are always open to challenge and they must be adaptively modified as understanding and experience of the system being managed increases'.

'It follows that more detailed monitoring surveys would increase the confidence in the validity of a TPC (i.e. narrow the uncertainty). This principle is built into the decision support system (DSS) by considering different levels of monitoring surveys'.

2.3 Principles of ecological water resources monitoring, ecological specifications and thresholds of potential concern

Monitoring in this report focuses on measuring the ecological state, i.e. the EC. EcoSpecs and TPCs therefore describe the present ecological state (PES) and/or the recommended ecological category (REC) for each of the biota and habitat indicators.

The key principles and concepts are the following:

- Data collated during field surveys during the EFR study or at the onset of the monitoring programme form the baseline.
- Future monitoring must compare conditions to the baseline.
- For rivers the EcoSpecs and TPCs therefore describe the baseline so monitoring can determine whether one is maintaining the PES, further degrading the system, or achieving the REC if different from the PES.
- Monitoring should be initiated soon after the baseline data has been collated to ensure that this data represents the recent baseline.
- Monitoring must be applied within an adaptive management framework.
- The concept of the TPCs provides the basis of a DSS. When TPCs are exceeded, management actions will be necessary.

Management actions are designed to maintain, or attain (if different from the PES) the REC. These management actions relate to the management objectives which are described in terms of the flow and quality (water quality) EcoSpecs. Additional land use objectives may also be described if non-flow related aspects are contributing to the PES of the system. One must therefore clearly distinguish between setting management objectives in terms of habitat to achieve/maintain certain ECs, and defining EcoSpecs for the biophysical responses that describe the ECs.

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

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

2.4 Different levels of monitoring

The design of a cost-effective monitoring programme is based on different levels of monitoring:

- Level 1: Desktop approaches at a high frequency (e.g. annually).
- Level 2: Surveys and specialist analysis at low frequency (e.g. every three years).

If level 1 monitoring indicates that TPCs are exceeded, level 2 monitoring surveys may need to be initiated to determine the management actions required to address potential problems. Level 1 and level 2 is included in the design of this monitoring programme.

3. Fish River: Ecological specifications and thresholds of potential concern

3.1 EFR Fish 1: Ecological specifications and thresholds of potential concern

EFR Fish 1 is situated upstream of Neckartal Dam. As such, it is in the ideal position to act as a monitoring control site if operation from Hardap Dam does not change from the present. The purpose of the control site would be to aid in the interpretation of monitoring results obtained at EFR Fish 2 and in the determination of the causes and source of changes from the baseline.

3.1.1 EFR Fish 1: Ecological specifications in terms of ecological categories

The ECs representative of broad qualitative EcoSpecs determined for the PES (Technical Report 27) is provided in Table 1. As this is a control site, only the PES is representative of the baseline.

Table 1. EFR Fish 1: EcoSpecs as ecological categories

Components	***PES***
Physico-chemical	C
Geomorphology	B/C
Fish	B
Macro-invertebrates	C
Instream	**B/C**
Riparian vegetation	B/C
Riverine fauna	B
EcoStatus	**B/C**

3.1.2 EFR Fish 1: Geomorphology ecological specifications and thresholds of potential concern

Pools in particular represent a critical ecological role, offering often the only surface water and aquatic habitat during the extended dry seasons and sometimes for years on end. Monitoring of the presence and condition of pool habitats is the most critical indicator for assessing habitat at the Fish River EFR sites. The TPCs are set as follows:

- At least 70% of the area of pools within the reach is maintained (relative to the December 2004 condition) at the end of the dry season.
- No net infilling or narrowing of the pools in more than one in three of the cross sections, relative to the baseline (2012) condition.

3.1.3 EFR Fish 1: Riparian vegetation ecological specifications and thresholds of potential concern

The EcoSpecs and TPCs for riparian vegetation (Table 2) are based on the PES of a B/C ecological category.

Table 2. EFR Fish 1: Riparian vegetation EcoSpecs and TPCs

Assessed component	Description
Perennial alien species invasion	
Zone assessed	Bank lining pool areas (Figure 2, section 5.3.2).
EcoSpecs	Maintain alien perennial species cover less than 15%.
TPC	Increase in alien perennial species cover above 15%.
Note/baseline	Baseline recorded <10% recorded during assessment on 15 June 2012.
Indigenous riparian woody cover	
Zone assessed	Bank lining pool areas (Figure 2, section 5.3.2).
EcoSpecs	Maintain woody cover above 60% within strips of vegetation (refer to photo for demarcated area).
TPC	A decrease in riparian woody species cover below 60% (within demarcated area) (Figure 2, section 5.3.2).
Note/baseline	Photo serves as baseline (Figure 2, section 5.3.2). Recorded during assessment on 15 June 2012.
Acacia karoo population structure	
Zone assessed	Upper zone, macro channel bank (MCB), floodplain.
EcoSpecs	Maintain population structure with a ratio of 70% adult, 20% sub-adult and 10% juvenile.
TPC	A decrease in adult proportion of the population below 70%, OR a decrease in the sub-adult proportion below 20%, OR a decrease in the juvenile proportion (excluding germinants) below 10%.
Note/baseline	*Acacia karoo* is harvested for wood and the seedlings and propagules are highly palatable to livestock which make it the most sensitive woody bank riparian species in terms of loss of species diversity. Recorded during assessment on 15 June 2012.
Phragmites (reed) cover	
Zone assessed	Riparian zone, excluding MCB.
EcoSpecs	Maintain reed cover below 10%.
TPC	An increase in reed cover above 10%.
Note/baseline	Baseline recorded <5% during assessment on 15 June 2012.

3.2 EFR Fish 2: Ecological specifications and thresholds of potential concern

3.2.1 EFR Fish 2: EcoSpecs in terms of ecological categories

The ECs representative of broad qualitative EcoSpecs determined for the PES and REC (Technical Report 27) is provided in Table 3. The objectives to improve the PES to the REC are provided in the last column.

Table 3. EFR Fish 2: EcoSpecs as ecological categories

Components	*PES*	*REC*	*Objectives to achieve the REC*
Physico-chemical	C	C	
Geomorphology	B/C	B/C	No improvement necessary as the floods cannot be provided.
Fish	B	B	Already in a B PES; no improvement required.
Macro-invertebrates	B	B	Already in a B PES; no improvement required.
Instream	**B**	**B**	Already in a B PES; no improvement required.
Riparian vegetation	C	C+	The floods cannot be provided. The only issue that can be addressed is non-flow related, i.e. addressing the overgrazing by goats. This would only improve the vegetation within the C category
Riverine fauna	B	B	Already in a B PES; no improvement required.
EcoStatus	**C**	**C+**	**The only improvement that can be made within the EcoStatus category is non-flow related, i.e. controlling grazing (goats) and only relevant for riparian vegetation. All other EcoSpecs therefore will describe the ECs for the PES.**

3.2.2 EFR Fish 2: Geomorphology ecological specifications and thresholds of potential concern

Pools in particular represent a critical ecological role, offering often the only surface water and aquatic habitat during the extended dry seasons and sometimes for years on end. Monitoring of the presence and condition of pool habitats is the most critical indicator for assessing habitat at the Fish River EFR sites. The TPCs are set as follows:

- At least 50% of the area of pools within the EFR reach is full at the end of the dry season (relative to the December 2011 condition).
- No net infilling or narrowing of the pools in more than one of the pool cross-sections relative to the 2012 condition.

3.2.3 EFR Fish 2: Water quality ecological specifications and thresholds of potential concern

The existing water quality sites (Technical Report 28) at which monitoring should take place are SW1 (downstream Seeheim), SW2 (downstream Naute Dam), and SW3 (downstream Neckartal

Dam). For information on the locality of the sites and the PES for the physico-chemical variables, refer to (Technical Report 27 and 28). The EcoSpecs and TPCs are provided in Table 4.

Table 4. EFR Fish 2: Water quality EcoSpecs

Metrics	***EcoSpecs***	***TPCs***
Inorganic salts[(a)]		
$MgSO_4$[(b)]	*Calculate if TPC for EC exceeded.* 95th percentile: ≤37 mg/ℓ.	95th percentile: 30 – 37 mg/ℓ.
Na_2SO_4[(b)]	*Calculate if TPC for EC exceeded.* 95th percentile: ≤51 mg/ℓ.	95th percentile: 41 – 51 mg/ℓ.
$MgCl_2$	*Calculate if TPC for EC exceeded.* 95th percentile: be ≤51 mg/ℓ.	95th percentile: 41 – 51 mg/ℓ.
$CaCl_2$	95th percentile: ≤21 mg/ℓ.	95th percentile: 17 – 21 mg/ℓ.
NaCl[(b)]	*Calculate if TPC for EC exceeded.* 95th percentile: ≤389 mg/ℓ.	95th percentile: 311 – 389 mg/ℓ.
$CaSO_4$	95th percentile: ≤351 mg/ℓ	95th percentile: 281 – 351 mg/ℓ.
Physical variables		
EC	95th percentile: ≤85 mS/m.	95th percentile: 68 – 85 mS/m.
pH	5th percentile: Range from 6.5 to 8.0. 95th percentile: Range from 8.8 to 9.2.	5th percentile: <6.7 and >7.8. 95th percentile: <8.6 and >9.0.
Temperature[(c)]	Small deviation from natural range.	Rely on biotic response data to evaluate whether the TPC for temperature is being reached.
Dissolved oxygen[(c)]	5th percentile: ≥7.5 mg/ℓ.	5th percentile: 7.8 – 7.5 mg/ℓ. Initiate baseline monitoring for this variable.
Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	Initiate baseline monitoring for this variable and maintain natural range.
Nutrients		
TIN	50th percentile: ≤0.7 mg/ℓ.	50th percentile: 0.56 – 0.7 mg/ℓ.
PO_4-P	50th percentile: ≤0.125 mg/ℓ.	50th percentile: 0.10 – 0.125 mg/ℓ.
Response variables		
Chl-*a* phytoplankton	50th percentile: <30 µg/ℓ.	50th percentile: 24 – 30 µg/ℓ.
Chl-*a* periphyton	50th percentile: ≤84 mg/m^2.	50th percentile: 67 – 84 mg/m^2.
Toxics		
Fluoride	95th percentile: ≤1.5 mg/ℓ.	95th percentile of the data: 1.2 – 1.5 mg/ℓ.
Other	95th percentile: Must be within the target water quality range (TWQR) as stated in DWAF (1996).	An impact is expected if the 95th percentile of the data exceeds the chronic effects value (CEV) as stated in DWAF (1996).

a Generate using Tool for Ecological Aquatic Chemical Habitat Assessment (TEACHA) when the TPC for EC is exceeded or salt pollution expected. *Note that inorganic salt concentrations were not available for the PES assessment.* Should the TPC for any integrated salt be exceeded, particularly Na_2SO_4, NaCl, $MgSO_4$ and $MgCl_2$ in this instance, consult a water quality specialist and check the validity of the EcoSpec and TPC by running TEACHA on the data used to determine the PES. If necessary, adjust the boundary for the EcoSpec and TPC for the relevant salt.

b) The concentration for this parameter probably exceeds the recommended EcoSpec (D ecological category).
c) No data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

3.2.4 EFR Fish 2: Diatom ecological specifications and thresholds of potential concern

The diatom data indicates that diatom-based water quality varies to great degrees throughout the year and is mainly driven by the flow conditions within the system. The main objective of this monitoring will be to determine, if the pool conditions improve during elevated flows as well as indicating pollution and salinity sources. The classification of ecological indicators and class ranking based on Van Dam et al. (1994) is provided in Table 5. EcoSpecs and TPCs are provided for both the wet season (or periods when the flow is elevated) (Table 6) and the dry season (or when the flow is low) (Table 7).

Table 5. Description of the ecological classification and interpretation of the class rankings according to Van Dam et al. (2004)

Metric and rank		
	Classification of indicator	***Description***
pH		
1	Acidobiontic	Optimal occurrence at pH <5.5.
2	Acidophilous	Mainly occurring at pH <7.
3	Circumneutral	Mainly occurring at pH values about 7.
4	Alkaliphilous	Mainly occurring at pH >7.
5	Alkalibiontic	Exclusively occurring at pH >7.
6	Indifferent	No apparent optimum.
Salinity		
1	Fresh	<3 mS/m
2	Fresh-brackish	<139 mS/m
3	Brackish-fresh	139 – 277 mS/m
4	Brackish	277 – 1385 mS/m
Oxygen requirements		
1	Continuously high	~100% saturation
2	Fairly high	>75% saturation
3	Moderate	>50% saturation
4	Low	>30% saturation
5	Very low	~10% saturation
Nitrogen uptake mechanism		
1	Nitrogen autotrophic–sensitive	Tolerating very small concentrations of organically bound nitrogen.
2	Nitrogen autotrophic–tolerant	Tolerating elevated concentrations of organically bound nitrogen.
3	Nitrogen heterotrophic–facultative	Needing periodically elevated concentrations of organically bound nitrogen.

Metric and rank		
	Classification of indicator	***Description***
4	Nitrogen heterotrophic–obligatory	Needing continuously elevated concentrations of organically bound nitrogen.
Saprobity		
1	Unpolluted to slightly polluted	BOD <2, O_2 deficit <15% (oligosaprobic).
2	Moderately polluted	BOD <4, O_2 deficit <30% (β-mesosaprobic).
3	Critical level of pollution	BOD <7 (10), O_2 deficit <50% (β-α-mesosaprobic).
3	Strongly polluted	BOD <13, O_2 deficit <75% (α-mesosaprobic)
4	Very heavily polluted	BOD <22, O_2 deficit <90% (α-meso-polysaprobic).
5	Extremely polluted	BOD >22, O_2 deficit >90% (polysaprobic).

Wet season EcoSpecs and TPCs

General characteristics of the diatom community and indicator species of importance are provided below.

- The diatom community should have an abundance of *Achnanthidium* species with a dominance of more than 10% as these species are indicators of recent elevated flows and high oxygenation rates.
- *Encyonopsis* species could also be dominant due to high oxygenation rates.
- Low abundances of the genus *Nitzschia* and *Gomphonema* are expected as nutrient and organic pollution levels improve.
- *Fragilaria* species should be dominant or sub-dominant as this genus is associated with dam releases or high flow.
- The general species composition would consist of a greater abundance of species with a preference for moderate to good water quality.

Table 6. EFR Fish 2: Physico-chemical TPCs for diatoms (wet season)

Physico-chemical metric	***EcoSpecs***	***Class rank[1]***	***TPC***
pH	6 – 8 Circumneutral.	3	≤2; ≥4
Salinity	Fresh brackish	2	>2
Oxygen	High to moderate saturation	1 – 3	>3
Nutrients	Elevated to periodically elevated concentrations of organically bound nitrogen.	2 – 3	>3
Organics	β to α mesosaprobic.	2 – 4	<2
SPI score	≥12	B – C EC	10 – 12

1 Refer to Table 5.

Dry season EcoSpecs and TPCs

General characteristics of the diatom community and indicator species of importance are outlined below.

- The diatom community should have an abundance of *Nitzschia* species with a dominance of more than 10% as this genus is indicative of nutrient rich waters. In particular the abundance of *N. frustulum* should increase to more than 20%. This species is an indicator species of high nutrient levels as well as salinity.
- *Gomphonema* and *Amphora* species with a preference for high organic loads and pollution should be more prominent e.g. *G. parvulum* and *A. pediculus*.
- The abundance of centric diatoms with a preference for salinity should increase e.g. *Stephanodiscus agassizensi*s and *Stephanodiscus hantzschii* although dominance is not expected.
- Species with a preference for slow flowing waters and elevated water temperatures should be present e.g. *Rhopolodia* species.
- Species with a preference for high salinities would become prolific and would include *N. frustulum*, *Amphora veneta*, *Nitzschia amphibian, Nitzschia perspicua, Nitzschia reversa, Nitzschia obtusa* var. *kurzii* and *Fragilaria fasciculata.*
- A general increase in abundance of *Mayamaea*, *Eolimna* and *Sellaphora* species are expected as organic levels increase or where cattle are present.
- The general species composition would consist of a greater abundance of species with a preference for deteriorated water quality.
- In the lower reaches of the Fish River a greater abundance of indicators for anthropogenic activities are expected (specifically relating to sewage) and would include *Gyrosigma scalproides*, *Navicula erifuga*, *Navicula libonensis*, *Nitzschia microcephala*, *Navicula symmetrica*, *Navicula veneta*, *Nitzschia communis* and *Nitzschia aurariae.*

Table 7. EFR Fish 2: Physico-chemical TPCs for diatoms (dry season)

Physico-chemical metric	***EcoSpecs***	***Class rank[1]***	***TPC***
pH	6 – 8 Circumneutral.	3	≤2; ≥4
Salinity	Fresh brackish	2	>2
Nutrients	Periodically elevated concentrations of organically bound nitrogen.	3	>3
Oxygen	Moderate to low saturation	3 – 4	≤4
Organics	α-mesosaprobic to α-meso-polysaprobic	4–5	>5
SPI Score	8 – 10	D EC	≤9.5

1 Refer to Table 5.

3.2.5 EFR Fish 2: Riparian vegetation ecological specifications and thresholds of potential concern

The EcoSpecs and TPCs for riparian vegetation (Table 8) are based on the PES of a C ecological category. EcoSpecs and TPCs tables for all ECs are provided in the electronic database.

Table 8. EFR Fish 2: Riparian vegetation EcoSpecs and TPCs

Criteria	***Description***
Perennial alien species invasion	
Zone assessed	Bank lining pool (Figure 3, section 5.3.2).
EcoSpecs (for PES)	Maintain alien perennial species cover less than 20%.
TPC (for PES)	Increase in alien perennial species cover above 20%.
Note/baseline	Baseline recorded <10% during assessment on 15 June 2012.
Indigenous riparian woody cover	
Zone assessed	Bank lining pool (Figure 3, section 5.3.2).
EcoSpecs (for PES)	Maintain woody cover above 60% within demarcated area (Figure 3, section 5.3.2).
TPC (for PES)	A decrease in riparian woody species cover below 60% (within demarcated area) (Figure 3, section 5.3.2).
Note/Baseline	Photo serves as baseline (Figure 3, section 5.3.2). Recorded during assessment on 15 June 2012.
Acacia karoo population structure	
Zone assessed	Upper zone, MCB, floodplain.
EcoSpecs (for PES)	Maintain population structure with a ratio of 70% adult, 20% sub-adult and 10% juvenile.
TPC (for PES)	A decrease in adult proportion of the population below 70%, OR a decrease in the sub-adult proportion below 20%, OR a decrease in the juvenile proportion (excluding germinants) below 10%.
Note/baseline	*Acacia karoo* is harvested for wood and the seedlings and propagules are highly palatable to livestock which make it the most sensitive woody bank riparian species in terms of loss of species diversity. Recorded during assessment on 15 June 2012.
Phragmites (reed) cover	
Zone assessed	Riparian zone, excluding MCB.
EcoSpecs (for PES)	Maintain reed cover below 10%.
TPC (for PES)	An increase in reed cover above 10%.
Note/baseline	Baseline recorded <5% during assessment on 15 June 2012.

3.2.6 EFR Fish 2: Fish ecological specifications and thresholds of potential concern

EcoSpecs and TPCs (Louw and Koekemoer (eds), 2010) relating to fish (site and reach) are provided in Table 9. The spatial frequency of occurrence (FROC) of EFR Fish 2 referred to in the reach TPCs (Table 9) is provided in Table 10 and indicates the FROC under reference, PES and

REC conditions as well as the TPCs for baseline (PES) conditions. A summary of EcoSpecs and TPCs per fish species is given in Table 11. This table also provides an indication of the potential causes and sources that may be responsible for the exceeding of species TPCs. Detailed spreadsheet information is available in the electronic database.

Important species for monitoring are *Labeobarbus aeneus* (BAEN), *Labeobarbus kimberleyensis* (BKIM), *Labeo capensis* (LCAP), *Labeo umbratus* (LUMB), *Clarias gariepinus* (CGAR) *Barbus paludinosus* (BPAU) and *Oreochromis mossambicus* (OMOS).

Table 9. EFR Fish 2: Fish EcoSpecs and TPCs

Criteria	***Description***
Metric 1: Species richness (Rank 1)	
PES: EFR Site	
Indicator spp.	All indigenous species.
EcoSpecs	All **six (6)** of the expected (under reference conditions) indigenous fish species were sampled during the baseline (EFR) survey.
TPC (Biotic)	Less than **5** fish species sampled during a survey when habitat can be sampled efficiently.
TPC (Habitat)	Loss in diversity, abundance and condition of velocity-depth categories and cover features.
PES: Reach	
Indicator spp.	All indigenous species
TPC (Biotic)	Baseline (PES) Fish Response Assessment Index (FRAI) score of 85% (B ecological category) calculated for the reach. Any decreased FROC in reach of a species (refer to sheet 5-FROC: Table 2) **or** FRAI scores decreasing below 77.5% (B/C ecological category).
Metric 2: Alien fish species (Rank 2)	
PES: EFR Site	
Indicator spp.	Any alien/introduced spp.
EcoSpecs	One alien fish species (OMOS) were sampled at the site during the baseline EFR survey. OMOS was recorded at 0,2 individual per min (indiv/min).
TPC (Biotic)	Presence of any additional alien/introduced species at site, or OMOS present at relative abundance > 0,3 indiv/min.
TPC (Habitat)	N/A
PES: Reach	
Indicator spp.	Any alien/introduced spp.
TPC (Biotic)	Increase in the number of alien species (>1 species in reach) or presence of any alien species other than OMOS.
Metric 3: Water column and slow deep (SD) habitats (Rank 3)	
PES: EFR Site	
Indicator spp.	BPAU, BAEN, and LCAP
EcoSpecs	The three indicator species of this metric BAEN, BPAU and LCAP were sampled at the site during the baseline EFR surveys.
TPC (Biotic)	BAEN **and/or** BPAU **and/or** LCAP absent during any survey.

Criteria	***Description***
TPC (Habitat)	Reduction in suitability and availability of SD habitats, water column-(depth) in pools (i.e. increased sedimentation of pools)
PES: Reach	
Indicator spp.	BPAU and BAEN
TPC (Biotic)	Any decreased FROC in reach of BAEN and BPAU (refer to sheet 5-FROC, column F: Table 2).
Metric 4: Overhanging and instream vegetation (Rank 4)	
PES: EFR Site	
Indicator spp.	BPAU
EcoSpecs	The only indicator species of this metric is BPAU, which was very abundant at the site during the baseline EFR surveys. BPAU was present at >5 individuals per minute (indiv/min).
TPC (Biotic)	BPAU absent during any survey.
TPC (Habitat)	Significant change in overhanging vegetation and instream vegetation habitats (through over grazing, chemical pollution, altered flow regime).
PES: Reach	
Indicator spp.	BPAU
TPC (Biotic)	Any decreased FROC in reach of BPAU (refer to sheet 5-FROC, column F: Table 2).
Metric 5: Slow shallow (SS) habitats (Rank 5)	
PES: EFR Site	
Indicator spp.	BPAU and CGAR
EcoSpecs	The two indicator species of this metric BPAU and CGAR were sampled at the site during the baseline EFR surveys.
TPC (Biotic)	BPAU **and** absent during any survey, and CGAR absent during two consecutive surveys.
TPC (Habitat)	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).
PES: Reach	
Indicator spp.	BPAU and CGAR
TPC (Biotic)	Any decreased FROC in reach of BPAU and CGAR (refer to sheet 5-FROC, column F: Table 2).
Metric 6: Water quality intolerance (Rank 6)	
PES: EFR Site	
Indicator spp.	BKIM and LCAP
EcoSpecs	The two indicator species of this metric group, BKIM and LCAP, were sampled at the site during the baseline EFR surveys. BKIM was sampled at 0,35 indiv/min while LCAP was abundant at 1,3 indiv/min.
TPC (Biotic)	LCAP and/or BKIM absent during any survey. High level of anomalies in all fish at site.
TPC (Habitat)	Decreased water quality.
PES: Reach	
Indicator spp.	BKIM and LCAP
TPC (Biotic)	Any decreased FROC in reach of BKIM and LCAP (refer to sheet 5-FROC, column F:

Criteria	*Description*
	Table 2).
Metric 7: Fast (flowing) habitats, substrate, flow dependant spp. (flow alteration) (Rank 7)	
PES: EFR Site	
Indicator spp.	LCAP, BAEN and BKIM
EcoSpecs	The two indicator species of this metric group, BAEN, LCAP and BKIM, were sampled at the site during the baseline EFR surveys. BAEN was present at 0,2 indiv/min, LCAP was present at 1,3 indiv/min and BKIM at 0,35 indiv/min.
TPC (Biotic)	BAEN **and/or** LCAP **and/or** BKIM absent during any survey.
TPC (Habitat)	Reduced frequency and duration of fast habitats (i.e. decreased flows), loss of rocky substrate quality, increased sedimentation or algal growth on rocky substrates.
PES: Reach	
Indicator spp.	LCAP, BAEN and BKIM
TPC (Biotic)	Any decreased FROC in reach of BAEN, BKIM and LCAP (refer to sheet 5-FROC, column F: Table 2).
Metric 8: Relative abundance (Rank 8)	
PES: EFR Site	
Indicator spp.	All indigenous species.
EcoSpecs	During baseline (EFR) surveys fish were sampled at **seven** individuals per minute using a SAMUS electrofisher (wading and from boat). Overall relative abundance was high.
TPC (Biotic)	It is estimated that relative abundance may vary greatly in a seasonal system like the Fish River, rendering it of low value as an indicator of deterioration. This variable was therefore excluded from other metrics). Relative abundance of **less than four** individual per minute sampled at the site (during same season and approximate similar flow conditions as baseline data) when habitat can be sampled efficiently and using comparable method.
TPC (Habitat)	N/a
PES: Reach	
Indicator spp.	N/a
TPC (Biotic)	N/a
REC: Reach	
EcoSpecs	An improvement from PES FROC in the reach for should be indicative of reaching/maintaining the REC (refer to 5-FROC sheet for more detail).

Table 10. Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species	*Reference FROC (A)*	*PES (REC) FROC (B)*	*PES (REC) FROC TPC (B)*
BAEN	4	3	2
BKIM	3	2	1
BPAU	5	5	4
CGAR	4	4	3
LCAP	5	5	4
LUMB	3	2	1

EcoSpecs and TPCs summarised per species, and an indication of the potential causes and sources that may be related to exceeding the TPCs, are provided in Table 11.

Table 11. EFR Fish 2: Summary of EcoSpecs and TPCs per fish species

Criteria	***Description***
Indigenous species: BAEN	
EcoSpec[1]	0,2 indiv/min
TPC	Absent during any survey.
Potential change in:	SD, fast shallow (FS) and fast deep (FD) habitats as well as water column and substrate.
Possible cause/source	Sedimentation of pools, flow modification, excessive algal growth on substrate, siltation of substrates, migration barriers.
Indigenous species: LKIM	
EcoSpec[1]	0,35 indiv/min
TPC	Absent during any survey.
Potential change in:	FS, FD and SD habitat as well as water quality.
Possible cause/source	Flow modification, pollution, migration barriers.
Indigenous species: BPAU	
EcoSpec[1]	>5 indiv/min
TPC	Absent during any survey.
Potential change in:	Water column, SD habitats and overhanging vegetation.
Possible cause/source	Flow modification (increased flows or extreme decrease in flows, sedimentation of pools, overgrazing, vegetation removal, alien vegetation encroachment.
Indigenous species: CGAR	
EcoSpec[1]	0,06 indiv/min
TPC	Absent during two consecutive surveys.
Potential change in:	SS and SD habitat.
Possible cause/source	Significant change in SS and SD habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).
Indigenous species: LCAP	
EcoSpec[1]	1,3 indiv/min
TPC	Absent during any survey.
Potential change in:	Water column, SD, FS and FD habitats. Substrate and water quality.
Possible cause/source	Sedimentation of pools, flow modification, excessive filamentous algal growth on substrate, siltation of substrates, pollution, migration barriers.
Indigenous species: LUMB	
EcoSpec[1]	0,01 indiv/min
TPC	Absent during two consecutive surveys.
Potential change in:	Water column, SD habitat and alien fish.
Possible cause/source	Sedimentation of pools, flow modification, competition with bottom feeding alien species (*Cyprinus carpio*).

Criteria	*Description*
Alien species: OMOS	
EcoSpec[1]	0,2 indiv/min
TPC	>0,3 indiv/min
Potential change in:	Fish species composition and population structure.
Possible cause/source	Stocking, successful reproduction and dispersion.

1 Electrofishing (individuals/minute) during baseline survey.

3.2.7 EFR Fish 2: Macro-invertebrate ecological specifications and thresholds of potential concern

Gomphidae were selected as the only macro-invertebrate indicator taxon for the EFR sites situated in the Fish River. This species has a strong preference for slow flow (0.1 – 0.6 m/s) and prefers sand-gravel-mud as substrate. It has a low sensitivity to water quality deterioration.

The following EcoSpecs and TPCs were defined for the early dry season only (Table 12). Early dry season is defined here as one to three months post high flows, when surface flow is sufficient to support flow-dependent species. Monitoring targets for macro-invertebrates were not set for the other two phases of the hydrological cycle partly because of the high natural variation expected in species composition and abundance.

Table 12. EFR Fish 2: Macro-invertebrate EcoSpecs and TPCs

EcoSpecs	*TPCs*
NASS2 Score[1] >70	NASS2 Score <78.
ASPT[2] >4.5	ASPT <4.8
Gomphid larva common or abundant (>B abundance).	Gomphid larvae rare or absent on any one survey.
Ecological Traits	
At least three of the five life-span categories present.	<three of the five life-span categories present.
Air-breathers <50% of taxa.	>50% of taxa present comprise air-breathers.
Filter-feeder abundance moderate.	Filter-feeder abundance rare or absent.
Macro-invertebrates in all four categories of current preferences present.	Macro-invertebrates in three or less of the current preference categories present.
Macro-invertebrates in all four categories of habitat preferences present.	Macro-invertebrates in three or less of the habitat preference categories present.
Warm, stenothermal taxa comprising <20%.	Warm, stenothermal taxa comprising >20%.
Taxa sensitive to water quality neither rare nor absent.	Abundance of taxa sensitive to water quality either rare or absent.
Alien macro-invertebrates absent.	Alien macro-invertebrates present.

1 Namibian Scoring System version 2.
2 Average score per taxon.

4. Fish River: Level 1 monitoring programme

Level 1 monitoring as proposed in this chapter is specific to ephemeral rivers such as the Fish River and due to the highly variable flow conditions that can be experienced. Pools have been identified as the critical habitats and the monitoring of this pool habitat is therefore the focus of the level 1 monitoring.

The level 1 monitoring programme is summarised in Table 13.

Table 13 Fish River: Level 1 monitoring programme

Indicator	***Monitoring action***	***Temporal scale (frequency and timing)***	***Spatial scale***
Geomorphology			
Presence of pools	Map the area of full pools either by using aerial, Google Earth, satellite imagery or with handheld GPS on site (see detail actions required below the table).	Annually: Nov or Dec.	EFR Fish 1 EFR Fish 2
Water quality and diatoms (described in chapter 5)			
Salinity/dissolved oxygen/temperature	Install loggers in pools that will measure these variables. Collect data.	Continuous. Collect data for analysis every month.	EFR Fish 1 EFR Fish 2 New site: EFR Fish Ai-Ais
All variables measured as part of the ESIA[1]	Existing monitoring to be continued (assumption).	Three monthly.	Existing sites[2]: SW1, SW2, SW3, SW4 New site: EFR Fish Ai-Ais
If the ESIA programme is discontinued, the alternative is the following:			
pH, Electrical Conductivity, nitrate-N, nitrite-N, ammonium-N, phosphate-P, metal ICP (inductively coupled plasma) spectrometric scan	Measure water quality variables.	Three monthly.	Existing sites[2]: SW1, SW2, SW3, SW4 New site: EFR Fish Ai-Ais
Diatoms	Field work linked to water quality measurements.	Six monthly.	EFR Fish 1 EFR Fish 2 EFR Fish Ai-Ais
Riparian vegetation			
Woody vegetation	Aerial photograph. Fixed point photos (linked to alternative geomorphological monitoring which requires a site visit).	Annually.	EFR Fish 1 EFR Fish 2

Indicator	*Monitoring action*	*Temporal scale (frequency and timing)*	*Spatial scale*
Reeds	Aerial photograph Fixed point photos (linked to alternative geomorphological monitoring which requires a site visit).	Annually.	EFR Fish 1 EFR Fish 2
Alien vegetation	Aerial photograph. Fixed point photos (linked to alternative geomorphological monitoring which requires a site visit).	Annually.	EFR Fish 1 EFR Fish 2
Macro-invertebrates			
Gomphid larvae	Visual assessment (see Appendix B) for use by regulatory agencies.	Annually.	EFR Fish 2

1 Environmental and social impact assessment undertaken for Neckartal Dam.
2 Existing water quality site names: See Technical Report 28 for map and description of water quality measuring sites.

The geomorphological monitoring actions are described in a step wise manner below:

- map the area of full pools from available aerial photography, Google Earth imagery or Landsat or other satellite imagery using Google Earth or a suitable GIS programme;
- compare the extent of the pool area with the baseline data.

Alternative:

- Take a handheld GPS to the EFR sites and map out the pools within the reach by recording GPS points at regular intervals along the water's edge.
- Take site photographs to document the condition of the site and pools.
- Upload the GPS points to Google Earth and map the extent of the pools as at the time of the site visit.
- Compare the extent of pools in the year of analysis with the baseline data and assess if the EcoSpecs have been met for the particular EFR site.

5. Fish River: Level 2 monitoring programme

Level 2 monitoring as proposed in this chapter is specific to ephemeral rivers such as the Fish River and due to the highly variable flow conditions that can be experienced. The monitoring programme is summarised in Table 14. Additional supporting information on methods for data collection and data analysis is also supplied.

Table 14 Fish River: Level 2 monitoring programme

Indicator	***Monitoring action***	***Temporal scale (frequency and timing)***	***Spatial scale***
Geomorphology			
Size and depth of pools	Resurvey of hydraulic cross-sections.	5 – 10 years (low priority).	EFR Fish 1 EFR Fish 2
Riparian vegetation			
Woody vegetation	Fixed point photos, field assessments.	Every three years.	EFR Fish 2
Reeds	Fixed point photos, field assessments.	Every three years.	EFR Fish 2
Alien vegetation	Fixed point photos, field assessments.	Every three years.	EFR Fish 2
Population structure	Field assessment.	Every three years.	EFR Fish 2
Fish			
BAEN, BKIM, LCAP, LUMB, CGAR, BPAU, and OMOS	Field assessment (electrofishing).	Every three years, dry season (same month as baseline).	EFR Fish 2 (key) EFR Fish 1 EFR Fish Ai-Ais
Macro-invertebrates			
Composition and abundance	Field assessment (NASS2[1]) (low priority).	Every three years. Within three months of a high flow event.	EFR Fish 2

5.1 Water quality and diatoms

Water quality and diatom monitoring forms part of the level 1 monitoring due to the frequency required. It does however form part of level 2 monitoring as well and is described here.

5.1.1 Rationale and objectives

The analysis of the water quality data will aid in the interpretation of biotic triggers and events. The diatom data indicates that diatom-based water quality in the Fish River varies to great degrees throughout the year and is mainly driven by the flow conditions within the system. From the diatom data it is evident that flow plays an important role in the amelioration of water quality throughout the system. This is especially important for the larger pools within the system which become isolated during dry periods. Organic and nutrient loading increases in these habitat types due to high evaporation rates, absence of flow and aquatic biota that use this habitat type as refuge areas. From the results it is evident that during summer organic pollution and elevated nutrient levels are high within the Fish River. There seems to be some measure of recovery during the winter months when temperatures are lower. The main objective of this monitoring level will be to determine if, pool conditions improve during elevated flows. The outcome of data analysis should focus on the general measure of system recovery of the Fish River as well as indicating pollution and salinity sources. At this level of monitoring the emphasis would be on the general diatom community composition and the temporal and spatial changes exhibited by the community under different flow conditions.

Within the context of the monitoring programme diatoms should be used as a water quality screening tool to provide information on diatoms as an additional response variable to:

- complement the physico-chemical driver component of the monitoring programme;
- provide additional information and interpretive results, especially at sites were physico-chemical data availability was poor or of low confidence;
- give an indication of the current pollution levels at a monitoring site according to the defined water quality class limits of the Specific Pollution sensitivity Index (SPI).

5.1.2 Data collection and analysis

The methods for collecting water quality information and diatoms are not detailed in this document, but should follow that outlined in DWAF (2008) and Technical Report 28. The following water quality parameters with the associated summary statistic to be used for monitoring are:

- pH: 5^{th} and 95^{th} percentiles;
- electrical Conductivity, ions, metals: 95^{th} percentiles;
- nutrients, i.e. total inorganic nitrogen (TIN) and ortho-phosphate: 50^{th} percentile (key parameter);
- diatoms: Average or mean of values;
- turbidity, dissolved oxygen (DO), temperature: narrative descriptions as no data are available at present.

Diatom data analysis should include the following data output or indicators:

- diatom based water quality score: Using the SPI to interpret results which include adjusted class limits;
- diatom based ecological classification according to Van Dam et al. (1994);
- the results from the Trophic Diatom Index (TDI) (Kelly and Whitton, 1995) should be included as this index provides the percentage pollution tolerant diatom valves in a sample

and was developed for monitoring sewage outfall (orthophosphate-phosphorus concentrations), and not general stream quality.

For diatoms, the variables of importance are oxygenation rates, organic pollution levels and organically bound nitrogen levels.

5.2 Geomorphology

5.2.1 Rationale and objectives

The objectives of the geomorphology monitoring are to assess if there are changes to the availability of physical habitats with altered flow and sediment regimes. In the Fish River EFR sites, the critical habitat is pool availability, whilst in the lower Orange River the size and diversity of the channel pattern indicates the diversity of instream and riparian habitats. Indicators of these habitat conditions have been identified and the EcoSpecs and TPCs linked to these.

5.2.2 Data collection and analysis

Periodic resurveying of the cross-sectional profiles at the EFR sites will provide quantitative measures of changes in the depth and width of pools that may occur due to enhanced sedimentation as a result of reduced flood scour events.

This surveying should only be initiated if there is concern regarding the potential pool infilling/shrinking due to the reduced floods and associated reduced scour potential (i.e. indicated by a reduction in pool area that is thought not to be related to insufficient flows. Using a theodolite Total Station or other high resolution survey equipment, the cross-section locations should be identified and resurveyed (refer to Technical Report 31 – Hydraulics for the location and baseline profile condition of the cross-sections).

The width and elevation of the bed of the pools should be compared with the survey information from the baseline (2012) condition and a comparison should be undertaken to assess if the EcoSpecs and TPCs are being met (level 2).

5.3 Riparian vegetation

5.3.1 Rationale and objectives

Riparian vegetation monitoring is undertaken to demonstrate whether or not there are changes to riparian vegetation structure or proportions of distinct riparian sub-communities in response to altered flow regimes. This will require measurement of vegetation response to non-flow related impacts (such as overgrazing) as well. Four components, each with EcoSpecs and TPCs of the riparian zone for the two sites on the Fish River have been selected for monitoring, with the premise that these four components sufficiently represent the response of the riparian zone as a whole:

- woody vegetation – Indigenous woody riparian species comprise one of the dominant community types within the riparian zone of the Fish River in general. It is usually associated with pools or other areas where soil moisture is usually elevated e.g. confluences with tributaries. This community has specific water and flood requirements;
- reeds – Also associated with pools, this is a different community type and one that may become problematic on the Fish River should flow become elevated or regulated;
- alien vegetation – The focus is on perennial alien species that may invade the riparian zone. *Prosopis* species are a good example of this and are known exclude indigenous vegetation under certain conditions;
- population structure – *Acacia karoo* is an upper zone and bank riparian indicator on the Fish River and is utilized for its wood. The seeds, pods and saplings are also browsed by game or livestock. For this reason it is necessary to monitor the population structure in addition to overall woody cover.

5.3.2 Data collection and analysis

The data collection is summarised in Table 14 and monitoring of the four components would entail:

- woody vegetation - estimation of aerial woody cover within demarcated areas;
- reeds – estimation of aerial reed cover on the marginal and lower zones and surrounding pools;
- alien vegetation – estimation of aerial cover of alien species, as well as recording the species present;
- population structure assessment – the following three size/age classes should be assessed: Adults, sub-adults and juveniles. This is seen to be necessary because a simple measure of aerial cover is unlikely to highlight the loss of younger individuals or a change in species composition. Each age/size class is given an estimated proportion (%) of the total population. Adults are considered large, fully reproductive individuals, sub-adults are medium, individuals with some but reduced reproduction and juveniles are saplings, (excludes germinants due to their seasonality and transient nature).

The demarcated areas within which monitoring should take place at EFR Fish 1 and 2 are illustrated in Figure 2 and 3.

Figure 2. Demarcated area at EFR Fish 1 within which riparian woody cover is to be monitored

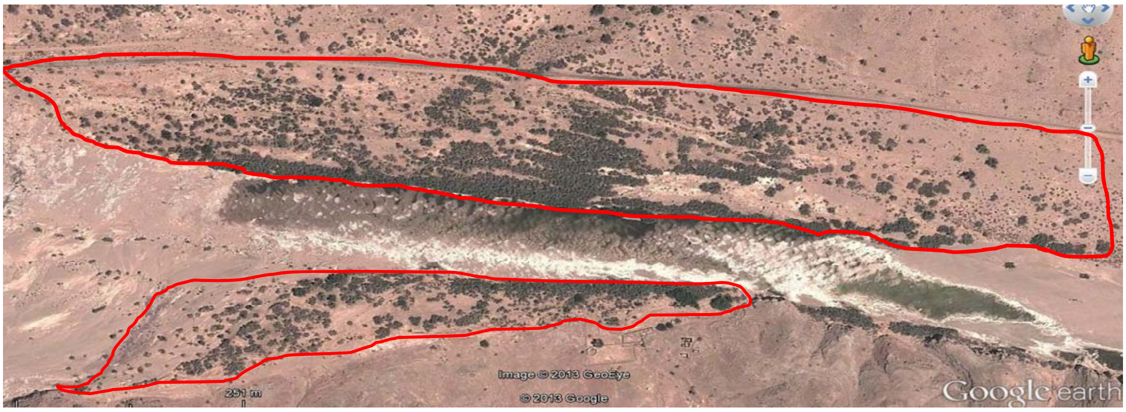

Figure 3. Demarcated area at EFR Fish 2 within which riparian woody cover is to be monitored

Aerial photos should be assessed to determine whether the aerial cover of woody vegetation and reeds has increased, decreased or remained constant. Attention should be paid to the season in which photos were taken, since the comparison of summer to winter photos may give a skewed impression. Fixed point photos should be visually assessed. Similarly woody vegetation, reeds and alien vegetation should be qualitatively rated as increasing, decreasing or stable.

Woody vegetation, reeds and alien species aerial cover that are assessed on site should be compared to previously monitored data to determine trends, and also compared to EcoSpecs and TPCs to determine whether any boundaries have been crossed. Similarly, population structure should be related to EcoSpecs and TPCs.

5.4 Fish

5.4.1 Objectives

The objective of the fish monitoring is as follows:

- determine the fish species composition at the EFR site or reach;
- determine the relative abundance of each species;

- determine the presence and abundance of alien fish species;
- determine the fish habitat composition at the site at the time of sampling;
- identify possible factors that may negatively impact on the fish assemblage (habitat and water quality deterioration).

5.4.2 Data collection and analysis

Fish monitoring should be conducted at least at EFR Fish 2, and supplemented with other sites in the direct vicinity (reach) of this EFR site. Other EFR sites (EFR Fish 1 and EFR Fish Ai-Ais) should preferably also be sampled during the same survey to allow for additional spatial data collection and broaden interpretation possibility of the data. The monitoring surveys should ideally be performed in the same period as the baseline surveys (presently baseline data is available for June and it is recommended that the baseline data be expanded to include at least one more survey conducted during the dry season).

The most important sampling method that should be applied during the survey is electrofishing. Electrofishing should be applied by wading in shallow water and from a boat in the deeper sections of the pools. Electrofishing should be applied for a minimum of 100 minutes in the EFR reach. The electrofishing data can be supplemented by the application of other non-destructive sampling methods such as the use of seine net, gill nets (range of mesh sizes) and cast nets.

All fish sampled should be kept alive, identified on-site to species level, total lengths measured/estimated, and any anomalies noted, and returned back into the system unharmed. Limited samples can be collected and fixed for the purpose of species verification in the laboratory.

The data should be analysed using the Fish Response Assessment Index (FRAI) (Kleynhans, 2007). Refer to EcoClassification section of the report for more detail regarding the model. The catch per unit effort (individuals per minute) should be calculated per species. The final results should then be used to determine if the EcoSpecs have been met, and whether any of the TPCs have been exceeded (refer to section 3.2.6 for more detail regarding the EcoSpecs and TPCs).

5.5 Macro-invertebrates

5.5.1 Objectives

The objectives of the macro-invertebrate monitoring are to assess the impacts of impoundments and associated irrigation developments on the health of the receiving aquatic ecosystem as reflected by the composition and abundance of macro-invertebrates, and to recommend mitigation measures to address any significant detrimental impacts identified, where appropriate.

5.5.2 Data collection and analysis

Macro-invertebrates in the Fish River should be collected according to the Namibian Scoring System version 2 (NASS2) (Palmer and Taylor, 2004). The NASS2 is based on the South African Scoring System version 5 (SASS5) (Dickens and Graham, 2002), which was modified slightly by adding tropical taxa that occur in northern Namibia (mainly snails), and excluding taxa that do not occur in Namibia, such as several families of cased caddisfly. The use of macro-invertebrates to monitor conditions of seasonal river systems, such as the Fish, needs careful consideration because of naturally high variation in macro-invertebrate populations in such systems. There are other environmental indicators for the Fish River that are likely to be more important and reliable as indicators of river health, such as the presence and depth of pools. Monitoring macro-invertebrates in the Fish River is therefore a low priority for long-term ecosystem monitoring.

The NASS2 was developed specifically for perennial streams and rivers and application to non-perennial systems needs to be made with caution. Scores are expected to vary depending on the hydrological conditions, and results therefore need to be interpreted accordingly. Macro-invertebrate data collected using the NASS2 method should therefore rather be analysed using the index that was developed for the Fish River for this project. The index is based on eight ecological traits, each of which are weighted in terms of their importance in defining the PES of benthic macro-invertebrates, and by implication, the river health. Each NASS2 taxon is allocated one category for each trait (provided electronically as part of the visual assessment of river condition for the Fish River). Details of the index are described in Technical Report 28, and not repeated here.

6. Orange River: Ecological specifications and thresholds of potential concern

EFR O5 is situated in the Orange River upstream of Sendelingsdrift within the /Ai-/Ais–Richtersveld Transfrontier Park.

6.1 Ecological specifications in terms of ecological categories

The ECs representative of broad qualitative EcoSpecs determined for the PES and REC (Technical Report 29) is provided in Table 15. The objectives to improve the PES to the REC are provided in the last column.

Table 15. EcoClassification results summary for the lower Orange River

Components	***PES***	***REC***	***Objectives to achieve the REC***
Physico-chemical	C	C	
Geomorphology	B/C	B	
Fish	B/C	B	Improve wet season baseflow and reinstate droughts.
Macro-invertebrates	B/C	B	Improve wet season baseflow and reinstate droughts.
Instream	**B/C**	**B**	Improve wet season baseflow and reinstate droughts.
Riparian vegetation	B/C	B	Improve wet season baseflow, control alien vegetation and grazing.
Riverine fauna	B	B	Already in a B PES; no improvement required
EcoStatus	**B/C**	**B**	**The key improvement is flow-related, i.e. improving the wet season baseflows and reinstating droughts. Water quality improvements required for the estuary will have a positive effect on the river. Control of alien vegetation and grazing, although difficult, will also benefit the river.**

6.2 Geomorphology

The TPCs are provided in Table 16 for the following two indicators:

- reach planform – channel width, presence of secondary channels and size of lateral and braid bars;
- channel dimensions (channel depth and width at the cross-section).

Table 16. EFR O5: Geomorphology TPCs

Indicator	***TPCs***
Reach planform	Relative to the 2012 condition of the site: Any increase in the area of alluvial bars; Any loss (abandonment) of secondary channels; Any reduction in active channel width.
Channel dimensions	The bed should not increase by more than 0,5 m in the active channel relative to the 2012 condition.

6.3 Water quality

EFR O5 represents that stretch of the Orange River from the confluence of the Fish (Namibia) and Orange rivers to the Orange River mouth, excluding the estuary. Two Department of Water Affairs (DWA) monitoring points (D8H007Q01 (Korridor Brand Kaross) and D8H012Q01 (Alexander Bay) were assessed for data. The EcoSpecs and TPCs are provided in Table 17.

Table 17. EFR O5: Water quality EcoSpecs and TPCs

Metrics	***EcoSpecs***	***TPCs***
Inorganic salts[a]		
$MgSO_4$	95^{th} percentile: ≤16 mg/ℓ.	95^{th} percentile: 13 – 16 mg/ℓ.
Na_2SO_4	*Calculate if TPC for EC exceeded.*	*Set TPC once EcoSpec has been calculated, as required.*
$MgCl_2$	95^{th} percentile: ≤15 mg/ℓ.	95^{th} percentile: 12 – 15 mg/ℓ.
$CaCl_2$	95^{th} percentile: ≤21 mg/ℓ.	95^{th} percentile: 17 – 21 mg/ℓ.
NaCl	*Calculate if TPC for EC exceeded.*	*Set TPC once EcoSpec has been calculated, as required.*
$CaSO_4$	95^{th} percentile: ≤351 mg/ℓ.	95^{th} percentile: 280 – 351 mg/ℓ.
Physical variables		
EC[b]	95^{th} percentile : ≤85 mS/m.	95^{th} percentile: >75 (present state) and < 85 mS/m.
pH	5^{th} percentile: range from 6.5 to 8.0. 95^{th} percentile: range from 8.8 to 9.2.	5^{th} percentile: <6.7 and >7.8 95^{th} percentile: <8.6 and >9.0.
Temperature	Small to moderate changes to temperature occur infrequently, with fluctuations of no more than 2°C.	Rely on biotic response data to evaluate whether the TPC for temperature is being reached.
Dissolved oxygen	5^{th} percentile: ≥7 mg/ℓ.	5^{th} percentile: 7.2 – 7.0 mg/ℓ. Initiate baseline monitoring for this variable.
Turbidity	Vary by a small amount from the natural range; minor silting of instream habitats acceptable.	Silting of habitats. Check biotic response for habitat-related changes.
Nutrients		
TIN	50^{th} percentile: ≤0.25 mg/ℓ.	50^{th} percentile: 0.2 – 0.25 mg/ℓ.

Metrics	*EcoSpecs*	*TPCs*
PO_4-P	50th percentile: ≤0.025 mg/ℓ.	50th percentile: 0.02 – 0. 025 mg/ℓ .
Response variables		
Chl-*a* phytoplankton[c]	50th percentile: ≤20 mg/ℓ.	50th percentile: 16 – 20 μg/ℓ.
Chl-*a* periphyton[c]	50th percentile: ≤21 mg/m².	50th percentile: 17 – 21 mg/m².
Toxics[d]	95th percentile: Within the chronic effects value (CEV) as stated in DWAF (1996).	An impact is expected if the 95th percentile of the data exceeds the TWQR as stated in DWAF (1996).

a Generate using TEACHA when the TPC for electrical conductivity is exceeded or salt pollution is expected. Should the TPC for any integrated salt be exceeded, particularly Na2SO4 and NaCl in this instance, consult a water quality specialist and check the validity of the EcoSpec and TPC by running TEACHA on the data used to determine the PES. If necessary, adjust the boundary for the EcoSpec and TPC for the relevant salt.
b TPC assigned based on expert judgement due to the small margin between present state and the upper limit of the category.
c Low confidence. EcoSpec and TPC boundaries may need adjusting as data become available.
d Although category boundaries exist in the Water quality Reserve manual (DWAF, 2008) for a number of toxicants, adherence to the CEV (DWAF, 1996) is recommended for the present state. Data collection and testing will need to be undertaken to assess the suitability of these objectives.

6.4 Diatoms

The diatom data indicates that there is a general deterioration in diatom-based water quality in this reach. Variables of importance are organic pollution levels, salinity and organically bound nitrogen levels. EcoSpecs and TPCs are provided in Table 18.

Table 18. EFR O5: Diatom EcoSpecs and TPCs

Physico-chemical metric	*EcoSpecs*	*Class rank*[1]	*TPC*
pH	6 – 8 Circumneutral.	3	≤2; ≥4
Salinity	Fresh brackish	2	>2
Oxygen	Elevated to periodically elevated concentrations of organically bound nitrogen.	2 – 3	>3
Nutrients	Moderate saturation	3	≤3
Organics	β-mesosaprobic to β-α-mesosaprobic	2 – 3	>3
SPI score	10 – 12	C/D EC	≤10

1 Refer to Table 5.

6.5 Riparian vegetation

The EcoSpecs and TPCs for riparian vegetation (Table 19) are based on the PES of a B/C and REC of a B.

Table 19. EFR O5: Riparian vegetation EcoSpecs and TPCs

Criteria	***Description***
Perennial alien species invasion	
Zone assessed	MCB and floodplain.
EcoSpecs (for PES)	Maintain alien perennial species below 15%.
TPC (for PES)	Increase in alien perennial species cover above 15%.
EcoSpecs (for REC)	Maintain alien perennial species less than 10%.
Note/baseline	VEGRAI[1] recorded <10% perennial aliens at the site, with *Prosopis glandulosa* and *Nicotiana glauca* occurring in low numbers. Recorded during assessment on 15 June 2012.
Indigenous riparian woody cover	
Zone assessed	MCB and floodplain.
EcoSpecs (for PES)	MCB: Maintain riparian woody species cover above 60%. Floodplain: Maintain riparian woody species cover above 40%.
TPC (for PES)	MCB: A decrease in riparian woody cover on the MCB below 60%. Floodplain: A decrease in riparian woody cover on the floodplain below 40%.
EcoSpecs (for REC)	MCB: Maintain riparian woody species cover above 70%. Floodplain: Maintain riparian woody species cover above 50%.
Note/baseline	MCB: VEGRAI estimation was >80% on the MCB. Floodplain: VEGRAI estimation was 50% on the floodplain. Both zones recorded during assessment on 15 June 2012.
Prosopis species invasion	
Zone assessed	All zones.
EcoSpecs (for PES)	Keep specific plant species cover to less than 5%.
TPC (for PES)	Increase in specific plant species cover above 5%.
EcoSpecs (for REC)	Keep specific plant species cover to less than 5%.
Note/baseline	Recorded as <5% during assessment on 15 June 2012.
N. glauca invasion	
Zone assessed	All zones.
EcoSpecs (for PES)	Keep specific plant species cover to less than 5%.
TPC (for PES)	Increase in specific plant species cover above 5%.
EcoSpecs (for REC)	Keep specific plant species cover to less than 5%.
Note/baseline	Recorded as <5% during assessment on 15 June 2012.
Indigenous riparian woody structure	
Zone assessed	MCB and floodplain.
EcoSpecs (for PES)	MCB: Maintain woody structure as closed woodland (Edwards, 1983). Floodplain: Maintain woody structure as open woodland.
TPC (for PES)	MCB: Opening up of the closed woodland. Floodplain: Opening up of the open woodland to sparse.

Criteria	***Description***
EcoSpecs (for REC)	MCB: Maintain woody structure as closed woodland (Edwards, 1983). Floodplain: Maintain woody structure as open woodland.
Note/baseline	MCB: Classified as closed woodland at the time of assessment, 15 June 2012. Floodplain: Classified as open woodland at the time of assessment, 15 June 2012.
Salix mucronata population cover	
Zone assessed	Riparian zone excluding MCB.
EcoSpecs (for PES)	Maintain population cover between 5% and 50%.
TPC (for PES)	A decrease in population cover below 5% OR an increase in population cover above 50%.
EcoSpecs (for REC)	Maintain population cover between 5% and 50%.
Note/baseline	Baseline recorded 5% cover on left bank and 30% cover on right bank during assessment on 15 June 2012.
Euclea pseudebenus population structure	
Zone assessed	MCB and floodplain.
EcoSpecs (for PES)	Maintain population structure with a ratio of 80% adult, 10% sub-adult and 10% juvenile.
TPC (for PES)	A decrease in adult proportion of the population below 80%, OR a decrease in the sub-adult proportion below 10%, OR a decrease in the juvenile proportion (excluding germinants) below 10%.
EcoSpecs (for REC)	Maintain population structure with a ratio of 80% adult, 10% sub-adult and 10% juvenile.
Note/baseline	Baseline recorded ratio of 90:5:5% (adult:sub-adult:juvenile) during assessment on 15 June 2012.
Searsia pendulina population cover	
Zone assessed	MCB
EcoSpecs (for PES)	Maintain at least 50% of total woody cover.
TPC (for PES)	Decrease in *S. pendulina* cover below 50% of total woody cover on MCB.
EcoSpecs (for REC)	Maintain at least 50% of total woody cover.
Note/baseline	Not recorded during assessment on 15 June 2012.
Acacia karoo population cover	
Zone assessed	MCB
EcoSpecs (for PES)	Maintain at least 10% of total woody cover.
TPC (for PES)	Decrease in *A. karoo* cover below 10% of total woody cover on MCB.
EcoSpecs (for REC)	Maintain at least 10% of total woody cover.
Note/baseline	Not recorded during assessment on 15 June 2012.
Phragmites (reed) cover	
Zone assessed	Marginal and lower zone.
EcoSpecs (for PES)	Maintain reed cover below 40%.
TPC (for PES)	An increase in reed cover above 40%.
EcoSpecs (for REC)	Maintain reed cover below 40%.

Criteria	***Description***
Note/baseline	Baseline recorded 30% (weighted average) (data: left bank marginal–0%, lower–0%; right bank marginal–80%, lower–50%) during assessment on 15 June 2012.
Sedge cover	
Zone assessed	Marginal and lower zone.
EcoSpecs (for PES)	Maintain sedge above 5%.
TPC (for PES)	Decrease in sedge cover below 5%.
EcoSpecs (for REC)	Maintain sedge above 10%.
Note/baseline	Baseline recorded >20% %) during assessment on 15 June 2012.

1 Vegetation Response Assessment Index (Kleynhans et. al., 2007)

6.6 Fish

EcoSpecs and TPCs (Louw and Koekemoer, 2010) relating to fish (site and reach) are provided in Table 20. The spatial FROC of EFR Fish 2 referred to in the reach TPCs (Table 20) is provided in Table 21 and indicates the FROC under reference, PES and REC conditions as well as the TPCs for baseline (PES) conditions. A summary of EcoSpecs and TPCs per fish species is given in Table 22. This table also provides an indication of the potential causes and sources that may be responsible for the exceeding of species TPCs. Detailed spreadsheet information is available in the electronic database.

Important species for monitoring are *Labeobarbus aeneus* (BAEN), *Labeobarbus kimberleyensis* (BKIM), *Labeo capensis* (LCAP), *Labeo umbratus* (LUMB), *Clarias gariepinus* (CGAR) *Barbus paludinosus* (BPAU), *Austroglanis sclateri* (ASCL), *Barbus hospes* (BHOS), *Barbus trimaculatus* (BTRI), *Mesobola brevianalis* (MBRE), *Pseudocrenilabrus philander* (PPHI), *Oreochromis mossambicus* (OMOS) and *Tilapia sparrmanii* (TSPA).

Table 20. EFR O5: Fish EcoSpecs and TPCs

Criteria	***Description***
Metric 1: Species richness (Rank 1)	
PES: EFR Site	
Indicator spp.	All indigenous species.
EcoSpecs	Eleven (11) of the expected (under reference conditions). Twelve indigenous fish species were sampled during the baseline (EFR) survey.
TPC (Biotic)	Less than ten (10) fish species sampled during a survey when habitat can be sampled efficiently.
TPC (Habitat)	Loss in diversity, abundance and condition of velocity-depth categories and cover features.
PES: Reach	
Indicator spp.	All indigenous species
TPC (Biotic)	Baseline (PES) FRAI score of 79.9% (B/C) calculated for the reach. Any decreased FROC in reach of especially ASCL, BAEN, BHOS, BKIM and BTRI (refer to sheet 5-FROC: Table 2) OR FRAI scores decreasing below 70% (Middle C ecological category).

Criteria	***Description***
Metric 2: Relative abundance (Rank 2)	
PES: EFR Site	
Indicator spp.	All indigenous species.
EcoSpecs	During baseline (EFR) surveys fish were sampled at 1,8 indiv/min using a SAMUS electrofisher (wading). Overall relative abundance was high.
TPC (Biotic)	Relative abundance of less than one indiv/min sampled at the site (during same season as baseline data) when habitat can be sampled efficiently and using comparable method.
TPC (Habitat)	N/a
PES: Reach	
Indicator spp.	N/a
TPC (Biotic)	N/a
Metric 3: FD and SD habitats, substrate, Flow dependant spp. (flow alteration) (Rank 3)	
PES: EFR Site	
Indicator spp.	BAEN and LCAP
EcoSpecs	The two indicator species of this metric group, BAEN and LCAP, were sampled at the site during the baseline EFR surveys. BAEN was present at 0,5 indiv/min while LCAP was present at 0.9 indiv/min.
TPC (Biotic)	BAEN **and/or** LCAP absent during any survey **or** present at relative abundance of <0.2 indiv/min for BAEN or <0.5 indiv/min for LCAP.
TPC (Habitat)	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates.
PES: Reach	
Indicator spp.	BAEN and LCAP
TPC (Biotic)	Any decreased FROC in reach of BAEN and LCAP (refer to sheet 5-FROC, column F: Table 2).
Metric 4: FS habitats (Rank 3)	
PES: EFR Site	
Indicator spp.	BAEN and BKIM
EcoSpecs	The two indicator species of this metric group, BAEN and BKIM were sampled at the site during the baseline EFR surveys. BAEN was present at 0,5 indiv/min while BKIM was very scarce at 0,01 indiv/min.
TPC (Biotic)	BAEN absent during any survey **or** BKIM absent during two consecutive surveys (>50% of time) **and/or** BAEN present at relative abundance of <0,2 indiv/min.
TPC (Habitat)	Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows).
PES: Reach	
Indicator spp.	BAEN and BKIM
TPC (Biotic)	Any decreased FROC in reach of BAEN and BKIM (refer to sheet 5-FROC, column F: Table 2).

Criteria	***Description***
Metric 5: Water quality intolerance (Rank 3)	
PES: EFR Site	
Indicator spp.	BKIM and LCAP
EcoSpecs	The two indicator species of this metric group, BKIM and LCAP, were sampled at the site during the baseline EFR surveys. BKIM was very scarce at 0,01 indiv/min while LCAP was abundant at 0,9 indiv/min.
TPC (Biotic)	No water quality intolerant species present, only moderately intolerant (BKIM) and moderately tolerant (LCAP). Fish therefore not a good indicator of water quality deterioration. LCAP absent during any survey, BKIM absent during two consecutive surveys (>50% of time) **or** present at relative abundance of <0,5 indiv/min for LCAP may indicate on deterioration.
TPC (Habitat)	Decreased water quality.
PES: Reach	
Indicator spp.	BKIM and LCAP
TPC (Biotic)	Any decreased FROC in reach of BKIM and LCAP (refer to sheet 5-FROC, column F: Table 2).
Metric 6: Water column (Rank 4)	
PES: EFR Site	
Indicator spp.	BAEN and MBRE
EcoSpecs	The two indicator species of this metric, BAEN and MBRE were sampled at the site during the baseline EFR surveys. BAEN was present at 0,2 indiv/min while MBRE was sampled at 0,14 indiv/min.
TPC (Biotic)	BAEN and/or MBRE absent during any survey **or** present at relative abundance of <0.2 indiv/min for BAEN or <0,05 indiv/min for MBRE.
TPC (Habitat)	Reduction in suitability of water column (i.e. increased sedimentation of pools).
PES: Reach	
Indicator spp.	BAEN and MBRE
TPC (Biotic)	Any decreased FROC in reach of BAEN and MBRE (refer to sheet 5-FROC, column F: Table 2).
Metric 7: Overhanging vegetation (Rank 5)	
PES: EFR Site	
Indicator spp.	PPHI and BPAU
EcoSpecs	The two indicator species of this metric, PPHI and BPAU were sampled at the site during the baseline EFR surveys. PPHI was present at 0,01 indiv/min while BPAU was sampled 0,09 indiv/min.
TPC (Biotic)	BPAU absent during any survey **or** PPHI absent during two consecutive surveys **or** BPAU present at relative abundance of <0,04 indiv/min.
TPC (Habitat)	Significant change in overhanging vegetation habitats.
PES: Reach	
Indicator spp.	PPHI and BPAU
TPC (Biotic)	Any decreased FROC in reach of PPHI and BPAU (refer to sheet 5-FROC, column F: Table 2).

Criteria	*Description*
Metric 8: Instream vegetation (Rank 5)	
PES: EFR Site	
Indicator spp.	BPAU and TSPA
EcoSpecs	The two indicator species of this metric, BPAU and TSPA were sampled at the site during the baseline EFR surveys. BPAU was present at 0,09 indiv/min while TSPA was very scarce at 0,01 indiv/min.
TPC (Biotic)	BPAU absent during any survey **and/or** TSPA absent during two consecutive surveys **and/or** BPAU present at relative abundance of <0,04 indiv/min.
TPC (Habitat)	Significant change in overhanging vegetation habitats (overgrazing, flow modification).
PES: Reach	
Indicator spp.	BPAU and TSPA
TPC (Biotic)	Any decreased FROC in reach of BPAU and TSPA (refer to sheet 5-FROC, column F: Table 2).
Metric 9: SS habitats (Rank 6)	
PES: EFR Site	
Indicator spp.	PPHI and MBRE
EcoSpecs	The two indicator species of this metric, PPHI and MBRE were sampled at the site during the baseline EFR surveys. PPHI was present at 0,01 indiv/min while MBRE was sampled 0,14 indiv/min.
TPC (Biotic)	PPHI absent during two consecutive surveys **and/or** MBRE absent during any survey **or** MBRE present at relative abundance of <0,01 indiv/min.
TPC (Habitat)	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).
PES: Reach	
Indicator spp.	PPHI and MBRE
TPC (Biotic)	Any decreased FROC in reach of PPHI and MBRE (refer to sheet 5-FROC, column F: Table 2).
Metric 10: Undercut Banks (Rank 7)	
PES: EFR Site	
Indicator spp.	PPHI and ASCL
EcoSpecs	The two indicator species of this metric, PPHI and ASCL were sampled at the site during the baseline EFR surveys. Both species were scarce, being present at 0.01 indiv/min.
TPC (Biotic)	PPHI **or** ASCL absent during two consecutive surveys.
TPC (Habitat)	Significant change in undercut bank habitats (e.g. bank erosion, reduced flows).
PES: Reach	
Indicator spp.	PPHI and ASCL
TPC (Biotic)	Any decreased FROC in reach of PPHI and ASCL (refer to sheet 5-FROC, column F: Table 2).

Criteria	*Description*
Metric 11: Alien fish species (Rank 8)	
PES: EFR Site	
Indicator spp.	Any Alien/introduced species
EcoSpecs	One indigenous introduced fish species (OMOS) was, sampled at the site during the baseline EFR survey. OMOS was recorded at 0,04 indiv/min.
TPC (Biotic)	Presence of any additional alien/introduced species at site, **or** OMOS present at relative abundance > 0,1 indiv/min.
TPC (Habitat)	N/a
PES: Reach	
Indicator spp.	Any alien/introduced species
TPC (Biotic)	
REC: Reach	
EcoSpecs	An improvement from PES FROC in the reach for especially BAEN, BHOS, BKIM, BPAU and BTRI should be indicative of reaching/maintaining the REC (refer to 5-FROC sheet for more detail).

Table 21. Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species	*Reference FROC (A)*	*PES FROC (B/C)*	*PES FROC TPC (B/C)*	*PES FROC (B)*
ASCL	1	1	0	1
BAEN	5	5	4	5
BHOS	4	4	0	4
BKIM	3	2	1	2
BPAU	4	3.5	2.5	3.5
BTRI	4	2	1	3
CGAR	4	4	3	4
LCAP	5	5	4	5
LUMB	1	0.5	0	0.5
MBRE	4	4	3	4
PPHI	4	3	2	3.5
TSPA	3	2	1	2.5

EcoSpecs and TPCs summarised per species, and an indication of the potential causes and sources that may be related to exceeding the TPCs are provided in Table 22.

Table 22. EFR O5: Summary of EcoSpecs and TPCs per fish species

Criteria	*Description*
Indigenous species: ASCL	
EcoSpec[1]	Present at 0,01 indiv/min (June baseline survey).
TPC	Absent during two consecutive surveys.

Criteria	*Description*
Potential change in:	Undercut banks, rocky substrate condition, FS and FD habitats.
Possible cause/source	Erosion, overgrazing, flow modification, excessive algal growth (nitrification) and siltation of substrates.
Indigenous species: BAEN	
EcoSpec[1]	Present at 0,56 indiv/min (June baseline survey).
TPC	Absent during any survey or present at <0,2 indiv/min.
Potential change in:	FD, FS and SD habitat. Rocky substrate and water column (adequate depth).
Possible cause/source	Sedimentation of pools, flow modification (decrease), excessive algal growth on substrate, siltation of substrates, and migration barriers.
Indigenous species: BHOS	
EcoSpec[1]	Present at 0,06 indiv/min (June baseline survey).
TPC	Absent during two consecutive surveys.
Potential change in:	SD and SS habitats. Rocky substrate.
Possible cause/source	Sedimentation of pools, excessive algal growth on substrate, and siltation of substrates.
Indigenous species: LKIM	
EcoSpec[1]	Present at 0,01 indiv/min (June baseline survey).
TPC	Absent during two consecutive surveys.
Potential change in:	FD, FS and SD habitat. Water quality.
Possible cause/source	Flow modification, pollution, and migration barriers.
Indigenous species: BPAU	
EcoSpec[1]	Present at 0,09 indiv/min (June baseline survey).
TPC	Absent during any survey or present at relative abundance <0,04 indiv/min.
Potential change in:	Overhanging and instream vegetation as well as Slow Shallow habitat.
Possible cause/source	Erosion, overgrazing, vegetation removal, alien vegetation encroachment, flow modification (decrease, change in seasonality).
Indigenous species: BTRI	
EcoSpec[1]	Present at 0,02 indiv/min (June baseline survey).
TPC	Absent during two consecutive surveys.
Potential change in:	SD and SS habitats and overhanging vegetation.
Possible cause/source	Sedimentation of pools, erosion, overgrazing, vegetation removal, alien vegetation encroachment, flow modification and increase in flows.
Indigenous species: CGAR	
EcoSpec[1]	Present at 0,02 indiv/min (June baseline survey).
TPC	Absent during two consecutive surveys.
Potential change in:	SD and SS habitats.
Possible cause/source	Significant change in SD and SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).

Criteria	*Description*
Indigenous species: LCAP	
EcoSpec[1]	Present at 0,9 indiv/min (June baseline survey).
TPC	Absent during any survey or present at relative abundance <0,5 indiv/min.
Potential change in:	Water column, FD, FS and SD habitat. Substrate and water quality.
Possible cause/source	Sedimentation of pools, flow modification, excessive filamentous algal growth on substrate, siltation of substrates, pollution, and migration barriers.
Indigenous species: LUMB	
EcoSpec[1]	Not sampled during baseline survey. Uncertain about presence. If present, very scarce and/or difficult to sample.
TPC	Due to uncertainty regarding presence, possible scarcity and general difficulty in sampling, this species is not a valid indicator for monitoring.
Potential change in:	Water column, SD, alien fish.
Possible cause/source	Sedimentation of pools, flow modification, competition with bottom feeding alien species (*Cyprinus carpio*).
Indigenous species: MBRE	
EcoSpec[1]	Present at 0,14 indiv/min (June baseline survey).
TPC	Absent during any survey or present at relative abundance <0.05 indiv/min.
Potential change in:	Water column, SD and SS habitats and water quality.
Possible cause/source	Significant change in SD and SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats), and pollution (especially decrease in oxygen).
Indigenous species: PPHI	
EcoSpec[1]	Present at 0,01 indiv/min (June baseline survey).
TPC	Absent during two consecutive surveys.
Potential change in:	SS habitat and undercut banks and overhanging vegetation.
Possible cause/source	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, and increased sedimentation of slow habitats). Significant change in undercut bank habitats (e.g. bank erosion, and reduced flows), overgrazing, vegetation removal, alien vegetation encroachment.
Indigenous species: TSPA	
EcoSpec[1]	Present at 0,01 indiv/min (June baseline survey).
TPC	Absent during two consecutive surveys.
Potential change in:	Instream vegetation, overhanging vegetation and SS habitats.
Possible cause/source	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality and increased sedimentation of slow habitats). Significant change in undercut bank habitats (e.g. bank erosion, reduced flows), overgrazing, vegetation removal, alien vegetation encroachment.
Alien species: OMOS	
EcoSpec[1]	Present at 0,04 indiv/min (June baseline survey).
TPC	> 0,1 indiv/min
Potential change in:	Fish species composition and population structure.

Criteria	*Description*
Possible cause/source	Stocking, successful reproduction and dispersion of alien species.

1 Electrofishing (individuals/minute) during similar conditions/season as baseline survey.

6.7 Macro-invertebrates

6.7.1 Indicator taxa

Perlidae (stoneflies), Baetidae (>2 spp.), Tricorythidae (stout crawlers), Atyidae (freshwater shrimps), Elmidae (riffle beetles), and Hydropsychidae (2 spp.) were selected as monitoring indicators for EFR O5. Table 23 outlines the habitat preferences of these taxa which are arranged in order of decreasing sensitivity to water quality deterioration. Cells shaded in green indicate taxa with a strong preference for a particular habitat while orange shaded cells indicate taxa with a partial preference for a particular habitat.

Table 23. EFR O5: Habitat preference of macro-invertebrate indicator taxa

Habitat metrics	*Perlidae*	*Baetidae*	*Tricorythidae*	*Atyidae*	*Elmidae*	*Hydropsychidae*
Flow						
Standing (<0.1 m/s)						
Slow (0.1 – 0.3 m/s)						
Moderate (0.3 – 0.6 m/s)						
Fast (>0.6 m/s)						
Substrate						
Hard						
Boulders/bedrock						
Loose cobbles						
Vegetation						
Sand, gravel, mud						
Water quality						
High (SASS >11)	12	12				
Moderate (SASS 7 – 10)			9	8	8	
Low (SASS 4 – 6)						6

6.7.2 EcoSpecs and TPCs

EcoSpecs and TPCs for the PES and REC at EFR O5 are provided in Table 24 below.

Table 24. EFR O5: Macro-invertebrate EcoSpecs and TPCs

PES EcoSpecs	***REC EcoSpecs***	***TPCs***
SASS5 Score >125	>150	<130
ASPT >5.9	>5.9	<6.0
MIRAI Score >60%	>80%	<63%
Indicator taxa		
At least 3/6 (50%) indicator taxa present.	4/6 (67%)	Three or more indicator taxa absent.
Perlidae present.		Perlidae absent on two or more consecutive surveys.
Baetidae >2 spp.		Baetidae < 2 spp. on any one survey.
Tricorythidae present.		Tricorythidae absent on two or more consecutive surveys.
Atyidae present.		Atyidae absent on any one survey.
Elmidae present.		Elmidae absent on two or more consecutive surveys.
Hydropsychidae present.		Hydropsychidae absent on two or more consecutive surveys.

7. Orange River: Level 1 monitoring programme

As the river is currently a perennial river, the level 1 monitoring focuses only on water quality and diatom monitoring. This is different from the Fish River where the focus is on pools due to the ephemeral nature of the river.

The level 1 monitoring programme is summarised in Table 25.

Table 25 Orange River: Water quality and diatom level 1 monitoring programme

Indicator	*Monitoring action*	*Temporal scale (frequency and timing)*	*Spatial scale[1]*
All variables measured as standard by DWA.	Improve frequency and include in formal monitoring programme.	Monthly, or determined by monitoring programme.	D8H012Q01 gauging weir
All variables measured as standard by DWA as well variable for RHP[2]	Install additional logger for RHP.	Continuous.	At the new DWA gauge at Sendelingsdrift
Diatoms	Field work (recommendation to incorporate park rangers to collect data).	Six monthly.	EFR O5

1 See Technical Report 29 and 30 for map and description of water quality measuring sites.
2 River Health Programme.

7.1 Water quality

It is recommended that samples be taken on a more regular basis at the D8H012Q01 gauging weir at Alexander Bay. Data used for water quality assessment was of low to moderate confidence as the most recent data were for 2003. Water quality monitoring programmes in the different areas of the Orange River Basin vary in frequency of measurement and water quality variables tested for. In general monthly grab samples are taken and at minimum the concentrations of the major cations and anions are determined. Samples should therefore be taken more regularly and according to a proper monitoring programme.

A *nutrient* management strategy also needs to be developed for areas where high levels of eutrophication can be seen from point sources. Main water quality issues in this section are elevated nutrient loads, elevations in salts and some elevated metals. All issues are exacerbated by fluctuating flows. 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, November 2010 and again in the Fish River Canyon during 2012. Causes are unknown although fish kills might be related to seasonal temperature changes and human skin conditions due to toxic blue-green algae or *Schistosome cercarial dermatitis* (Palmer, Nepid Consultants, pers. comm., November 2010).

Some emphasis should therefore be placed on nutrients and determining the sources of these elevated nutrients. Toxic blue-green algae are appearing in both the Fish and Orange River systems. Sources should be identified and source-directed controls and management strategies should be implemented to reduce nutrient loads. However, more regular monitoring should be the first step to identifying the scope of the problem. Together with diatom monitoring at EFR O5, a clearer picture of water quality status will develop and effective management can then be undertaken.

7.2 Diatoms

The approach to data analysis is the same as outlined for the Fish River (Section 3.2.2) and the classification of ecological indicators and class ranking based on Van Dam et al. (1994) (Table 5) should be used as guideline.

The outcome of data analysis should focus on the general measure of system recovery of the Orange River as well as indicating increasing organic pollution nutrients and salinity sources. The emphasis of the monitoring would be on the general diatom community composition and the temporal and spatial changes exhibited by the community under different flow conditions. The diatom data indicates that diatom-based water quality in the upper reaches of MRU Orange G is of moderate quality and there is a gradual deterioration in water quality downstream in the MRU due to increased salinity, nutrients and organic pollution levels. Elevated flows do play an important role in ameliorating the effects of deteriorated water quality and allows for system recovery.

8. Orange River: Level 2 monitoring programme

The monitoring programme is summarised in Table 26. Additional supporting information on data collection and analysis is also supplied.

Table 26 Orange River: Level 2 monitoring programme

Indicator	*Monitoring action*	*Temporal scale (frequency and timing)*	*Spatial scale*
Geomorphology			
Channel pattern (planform) (low priority)	Assessment of aerial photographs or high resolution satellite imagery.	Every five years.	EFR O5
Active channel size (very low priority)	Resurvey of the hydraulic cross-sections at each EFR site.	When triggered by other indicators.	EFR O5
Riparian vegetation			
Woody vegetation	Field assessments.	Every three years.	EFR O5
Reeds	Field assessments.	Every three years.	EFR O5
Alien vegetation	Field assessments.	Every three years.	EFR O5
Sedges	Field assessments.	Every three years.	EFR O5
Population structure	Field assessment.	Every three years.	EFR O5
Fish			
BAEN, BKIM, LCAP, LUMB, CGAR, BPAU, ASCL, BHOS, BTRI, MBRE, PPHI, OMOS and TSPA	Field assessment (electrofishing).	Every three years (dry season, same as baseline).	EFR O5 and other sites in MRU[1]
Macro-invertebrates			
Composition and abundance	Field assessment (SASS5) (high priority).	Every three years.	EFR O5

8.1 Geomorphology

8.1.1 Objective

Channel pattern (planform): Aerial photographs or satellite images taken over time will be used to record changes in channel patterns and gross morphology, which will provide a macro-level assessment of change in riverine habitat. The secondary channels and diversity of morphological features within the reach are indicative of the habitat diversity present at the site. Reduced floods and flow variability tend to cause abandonment of secondary channels and homoginisation of the riparian zone.

Active channel size: Reduced floods and flow stabilisation may cause a reduction of the aquatic habitat through channel narrowing and infilling (becoming shallower).

8.1.2 Data collection and analysis

Channel pattern (planform): Available Google Earth, or other high resolution satellite imagery or aerial photograph should be used to evaluate the EFR reach morphology. Presence of secondary (braided) channels, open sandy braid and point bars and the width of the active channel should be noted. The available imagery at the site of the survey should be compared with the baseline (2012) condition as well as the older aerial photographic record. Undesirable changes, such as excessive channel narrowing, loss of secondary channels and/or enhanced vegetation encroachment of the alluvial bars should be identified.

Active channel size: Using a theodolite Total Station or other high resolution survey equipment, the cross-section locations should be identified and resurveyed (refer to Technical Report 31 – Hydraulics for the location and baseline profile condition of the cross-sections). The width and elevation of the active channel should be compared with the survey information from the baseline (2012) condition and a comparison should be undertaken to assess if the EcoSpecs and TPCs are being met.

8.2 Riparian vegetation

8.2.1 Objectives

The objectives of the riparian vegetation monitoring are to demonstrate whether or not there are changes to riparian vegetation structure or proportions of distinct riparian sub-communities in response to altered flow regimes. This will require measurement of vegetation response to non-flow related impacts (such as overgrazing) as well. Five components, each with EcoSpecs and TPCs of the riparian zone have been selected for monitoring, with the premise that these four components sufficiently represent the response of the riparian zone as a whole:

- woody vegetation – indigenous woody riparian species comprise one of the dominant community types within the riparian zone of the Orange River in general. It is usually associated with banks or floodplains, but some species are specific to marginal or lower zone features;
- reeds – this is a distinct community type that may become problematic where flow becomes regulated;
- alien vegetation – the focus is on perennial alien species that may invade the riparian zone. *Prosopis* species and *Nicotiana glauca* are a good example of this and are known exclude indigenous vegetation under certain conditions;
- sedges – a distinct marginal and lower zone community type that provides inundated macrophyte habitat to instream fauna.

- population structure – certain species are noted for their contribution to the riparian zone and as such their population structure or extent should be monitored. *Prosopis* species and *N. glauca* are problematic alien populations; *S. mucronata* is one of the few marginal and lower zone woody riparian indicators; *A. karoo, S. pendulina* and *E. pseudebenus* are upper zone and bank riparian indicators (the latter two also being endemic).

8.2.2 Data collection and analysis

Aerial cover should be estimated for each zone for various riparian vegetation components according to Tables 27 to 30. The data shown in both tables are actual estimations and form part of the baseline monitoring information collected at EFR O5 during 15 June 2012.

A basic assessment of population/proportion structure is required for *Prosopis* species, *N. glauca*, *S. mucronata*, *A. karoo, S. pendulina* and *E. pseudebenus* once every three years when the site visit occurs. *Prosopis* species, *N. glauca*, *S. mucronata*, *A. karoo* and *S. pendulina* require an estimate of specific cover within the total woody vegetation cover for the respective zone. The following three size/age classes of *E. pseudebenus* should be rated and assessed: Adults, sub-adults and juveniles. This is seen to be necessary because a simple measure of aerial cover is unlikely to highlight the loss of younger individuals or a change in species composition. Each age/size class is given an estimated proportion (%) of the total population. Adults are considered large, fully reproductive individuals, sub-adults are medium, individuals with some but reduced reproduction and juveniles are saplings, (excludes germinants due to their seasonality and transient nature).

Table 27. EFR O5: Aerial cover estimation for woody riparian vegetation (left bank)

	% aerial cover in different woody vegetation zones				
	Marginal	***Lower***	***Upper***	***Upper MCB***	***Floodplain***
Vegetation components	***0 – 2 m***	***2 – 12 m***	***12 – 42 m***	***42 – 47 m***	***47 – 97 m***
Woody riparian	0	5	5	90	50
Woody terrestrial	0	0	0	0	10
Non-woody (incl. reeds)	10	10	5	0	5
Perennial alien	0	0	5	5	5
Open (alluvium)	0	0	0	5	30
Open (bedrock)	90	85	85	0	0

Table 28. EFR O5: Aerial cover estimation for woody riparian vegetation (right bank)

	% aerial cover in different woody vegetation zones			
	Marginal	***Lower***	***Upper***	***Upper MCB***
Vegetation components	***0 – 3 m***	***3 – 13 m***	***13 – 43 m***	***43 – 48 m***
Horizontal distance start (m)	0	3	13	43
Horizontal distance end (m)	3	13	43	48
Woody riparian	10	40	10	80
Woody terrestrial	0	0	0	0

	% aerial cover in different woody vegetation zones			
	Marginal	***Lower***	***Upper***	***Upper MCB***
Vegetation components	***0 – 3 m***	***3 – 13 m***	***13 – 43 m***	***43 – 48 m***
Non-woody (incl. reeds)	40	20	5	5
Perennial alien	0	0	0	0
Open (alluvium)	0	5	5	10
Open (bedrock)	50	35	80	5

Table 29. EFR O5: Aerial cover estimation for non-woody riparian vegetation (left bank)

	% aerial cover in different non-woody vegetation zones				
	Marginal	***Lower***	***Upper***	***Upper MCB***	***Floodplain***
Vegetation components	***0 – 2 m***	***2 – 12 m***	***12 – 42 m***	***42 – 47 m***	***47 – 97 m***
Reeds	0	0	0	0	0
Bullrushes	0	0	0	0	0
Sedges	5	10	5	0	0
Dicot forbs	0	0	0	0	0
Open (e.g. sand, water, rock)	90	85	85	85	85
Grasses	5	5	10	5	10
Low woody (≤50 cm)	0	0	0	10	5
Litter	0	0	0	0	0
Alien vegetation	0	0	0	0	0

Table 30. EFR O5: Aerial cover estimation for non-woody riparian vegetation (right bank)

	% aerial cover in different non-woody vegetation zones			
	Marginal	***Lower***	***Upper***	***Upper MCB***
Vegetation components	***0 – 3 m***	***3 – 13 m***	***13 – 43 m***	***43 – 48 m***
Reeds	40	30	0	0
Bullrushes	0	0	0	0
Sedges	10	25	5	0
Dicot forbs	0	0	0	0
Open (e.g. sand, water, rock)	50	40	80	85
Grasses	0	5	10	10
Low woody (≤50 cm)	0	0	5	5
Litter	0	0	0	0
Alien vegetation	0	0	0	0

8.3 Fish

Fish monitoring should be conducted at least at EFR O5, and supplemented with other sites in the direct vicinity (reach) of this EFR site. The monitoring surveys should ideally be performed in the same period as the baseline surveys (presently baseline data available for winter/June).

The most important sampling method that should be applied during the survey is electrofishing. Electrofishing should be applied by wading in shallow water and from a boat in the deeper sections of the pools. Electrofishing should be applied for a minimum of 100 minutes in the EFR reach. The electrofishing data can be supplemented by the application of other non-destructive sampling methods such as the use of seine net, gill nets (range of mesh sizes) and cast nets.

All fish sampled should be kept alive, identified on-site to species level, total lengths measured/estimated, and any anomalies noted, and returned back into the system unharmed. Limited samples can be collected and fixed for the purpose of species verification in the laboratory.

The methodology for data analysis are the same for the Fish River (refer to section 5.4.2).

8.4 Macro-invertebrates

8.4.1 Objectives

The objectives of the macro-invertebrate monitoring are to assess the impacts of impoundments and associated irrigation developments on the health of the receiving aquatic ecosystem as reflected by the composition and abundance of macro-invertebrates, and to recommend mitigation measures to address any significant detrimental impacts identified, where appropriate.

8.4.2 Data collection and data analysis

Macro-invertebrates in the Orange River should be collected and analysed using the SASS5 (Dickens and Graham, 2002). This rapid method of quantifies the health of perennial rivers and streams, and is based on the presence of major macro-invertebrate groups (mostly families), each of which have been allocated a "sensitivity" value which ranges from 1 (tolerant) to 15 (Highly Sensitive). The composition and abundance of macro-invertebrates in perennial streams and rivers provide a useful indication of river health, and are used worldwide to monitor ecological responses of freshwater ecosystems to development and management interventions. Baseline data on macro-invertebrates in the lower Orange River were collected using the SASS5/NASS2 biomonitoring index (Technical Report 30), and the same method is recommended for long-term monitoring in the lower Orange River at EFR O5. Macro-invertebrate data collected using the SASS5 method should be analysed using the Macro Invertebrate Response Assessment Index (MIRAI) (Thirion, 2007). This index quantifies the extent to which the observed invertebrate assemblage and abundances differ from the reference (natural) assemblage and abundances. Details of the method are described in Technical Report 30, and not repeated here.

9. Orange River Estuary: Ecological specification and thresholds of potential concern

The Orange Estuary, situated between the towns of Alexander Bay in the Northern Cape Province, South Africa and Oranjemund in Namibia has an area of about 2,700 ha. The estuary of the Orange River comprise an (almost) permanently open river mouth, a deeper tidal basin, a braided channel system (located between sand banks covered with pioneer vegetation) and a severely degraded saltmarsh on the south bank of the river mouth. The entire estuary from the mouth to about 12 km upstream should to be monitored, while the fish component needs to be monitored up to Brand Kaross (~ 20 km upstream).

9.1 Ecological specification in terms of ecological categories

The ECs representative of broad qualitative EcoSpecs for the Orange Estuary is provided in Table 31 (Technical Report 31). As the Orange Estuary is a Ramsar site the EC is provided in terms of the REC to ensure adherence to designated Ramsar criteria and protected area status requirements.

Table 31 Ecological classification results summary for the Orange Estuary

Components	***PES***	***REC***	***Objectives to achieve the REC***
Hydrology	D	D	Decrease baseflows in winter (reinstate droughts).
Hydrodynamics	C	B	Facilitate mouth closure in winter two to four times in 10 years.
Water quality	D	C	Reduce nutrient input in lower Orange River.
Physical habitat	**B**	**B**	Already in a B PES so no improvement required.
Microalgae	E	D	Reduce baseflows in winter and decrease nutrient input.
Macrophytes	D	C	Reduce soil salinities, reduce nutrient input, remove cause way, control grazing and alien vegetation.
Invertebrates	D	B	Reduce baseflows in winter and facilitate mouth closure.
Fish	D	C	Reduce baseflows in winter and facilitate mouth closure, control fishing.
Birds	E	D	Reduce baseflows in winter and facilitate mouth closure.
EcoStatus	**D**	**C**	**Reduce flows, facilitate mouth closure, improve vegetation cover and food sources (invertebrates and fish).**

Remedial actions required to improve the health of the system include:

- decreasing the winter baseflows sufficiently to allow for mouth closure and related back flooding of the saltmarshes with brackish water to reduce soil salinities;
- controlling the fishing effort on both the South African and Namibian side through increased compliance and law enforcements. This also required the alignment of the fishing regulations (e.g. size and bag limits) on both side of the transboundary estuary;

- removal of the remnant causeway that still transects the saltmarshes to improve circulation during high flow and floods events. This will also assist with increasing the water exchange into the lower marsh areas;
- decreasing nutrient input from the catchment downstream of Vioolsdrift, through improved agricultural practices.

9.1.1 *Abiotic ecological specification and thresholds of potential concern*

The EcoSpecs and TPCs for the abiotic components (hydrology, hydrodynamics, water quality, and sediment dynamics) of the Orange Estuary (Table 32) are based on the REC of a C ecological category.

Table 32. Orange Estuary: EcoSpecs and TPCs for abiotic components

Component	***EcoSpecs***	***TPCs***
Hydrology		
	Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	Low flow range: 2 – 5 m^3/s. Low flow duration: 2 – 3 months at a time during the low flow period. Low flow frequency: 2 – 4 years out of 10.
Hydrodynamics		
	Maintain a mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality	Mouth Closure: 2 months < closure > 4 months in 10 years. Water level: >2.5 m MSL.
Salinity		
	Salinity intrusion should not cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae (see above)	River inflow (drought flows = 10% of the time): 25 < salinity >40 lower reaches (0 – 6 km) 10 < salinity > 40 upper reaches (6 – 12 km) River inflow (low flow): 20 < salinity >30 lower reaches for 5 < months >7/annum. 0 < salinity >5 upper reaches for 5 < months >7/annum. River inflow (high flows): Salinity <1 for >7 months of the year.
System variables		
	pH, DO and turbidity not to exceed TPCs for biota	River inflow (low flow): 6.5< pH >8.5. River inflow (low flow): DO <4 mg/ℓ. River inflow (low flow): Turbidity – naturally turbid (can range between 10 – 100 NTU). River inflow (high flow): 6.5< pH >8.5. River inflow (high flow): DO <4 mg/ℓ. River inflow (high flow): Turbidity – naturally turbid (can be >200 NTU). Estuary (low flows): 6.5< pH >8.5. Estuary (low flows): DO <4 mg/ℓ.

Component ***EcoSpecs***	***TPCs***
	Estuary (high flows): 6.5< pH >8.5. Estuary (high flows): DO <4 mg/ℓ.
Inorganic nutrients	
Concentrations not to cause in exceedance of TPCs for macrophytes and microalgae.	River inflow (low flow): DIN[1] >100 μg/ℓ; DRP[2] >30 μg/ℓ. River inflow (high flow): DIN >150 μg/ℓ; DRP >30 μg/ℓ. Estuary (low flow): DIN >100 μg/ℓ; DRP >30 μg/ℓ (except during upwelling when concentrations in saline areas can be higher). Estuary (high flow): DIN >150 μg/ℓ; DRP >30 μg/ℓ.
Toxics	
Toxic substances not to cause exceedence of TPCs for biota.	River inflow: Trace metals (apply freshwater quality guidelines – DWAF (1996)). River inflow: Pesticides/herbicides (to be determined). Estuary: Trace metals – concentrations in estuary waters exceed target values as outlined in SA Water Quality Guidelines for coastal marine waters (DWAF, 1995). Baseline studies to be undertaken before TPCs can be set for trace metals in sediments. Estuary: Trace metals –concentrations in estuary waters exceed target values as outlined in DWAF (1995). Baseline studies to be undertaken before TPCs can be set for trace metals in sediments. Pesticides/herbicides: Baseline studies to be undertaken before TPCs can be set (preliminary TPC = when detected).
Sediment dynamics	
Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota.	Average clay content of suspended sediments in river upstream of estuary >65%.

1 Dissolved inorganic nitrogen.
2 Dissolved reactive phosphorus.

9.1.2 *Biotic ecological specification and thresholds of potential concern*

The EcoSpecs and TPCs for the biotic components (microalagae, macrophytes, invertebrates, fish and birds) of the Orange Estuary (Table 33) are based on the REC of a C ecological category. The TPCs are set as follows:

Table 33. Orange Estuary: EcoSpecs and TPCs for biotic components

Component ***EcoSpecs***	***TPCs***
Microalgae	
Phytoplankton biomass and cell density should not exceed 20 μg/ℓ and 10,000 cells/ml (typical of blooms) respectively. Median phytoplankton and MPB[1]	Median phytoplankton chl-a should <8 μg/ℓ under 'normal flows'. Phytoplankton cell density should be >10,000

Component	***EcoSpecs***	***TPCs***
	biomasses should not exceed 8 µg/ℓ and 42 mg/m² (TPC of 'very high' biomass). A 5% decrease in phytoplankton chl-a will relate to a 5% increase in microalgal score. This is mostly related to flow (low flow = higher residence time) and nutrients.	cells/ml 'normal flows'. Median MPB biomass should not be >42 mg/m² under 'normal flows'.
Macrophytes		
	Maintain the diversity of macrophyte habitats in the estuary. Reeds and sedges covering approx. 300 ha, submerged macrophyte *Stuckenia pectinata* (pondweed) occurs in sheltered areas (approx. 1 ha). Macroalgae cover less than 1 ha. Vegetation cover increases in desertified marsh area due to removal of causeway and improvement of tidal and flood channels. More than 50% of this area vegetated (approx. 250 ha)	Further sedimentation in main channel and colonisation by vegetation. 50 % loss of reed and sedge habitats in non-flood year due to salinity changes. No pondweed in non-flood years due to high turbidity. Macroalgae cover more than 1 ha due to low flow conditions and increase in nutrients. Less than 200 ha vegetation cover in the desertified marsh area due to limited rehabilitation efforts.
Invertebrates		
	Retain present state species richness and mix (low species abundance, high dominance). However, under the present state one or two species are always present at high densities compared to others (e.g. *Pseudodiaptomus hessei* and *Ceratonereis keiskama*). This translates in to high dominance of one or two species, both in the plankton and in the benthic community. For a C category the higher densities need to be highly variable in terms of abundance within and between years. This requires that the mouth should close aperiodically for months at a time – approx. every three to four years. Indicator species such as *Capitella capitata,* should not dominate benthic species abundance at the majority of sampling sites since their presence indicates anoxia conditions in the sediment. However, *Capitella* will naturally occur in high abundance in stagnant or poorly drained backwater areas.	Species richness is greater than 20 for zooplankton and macroinvertebrates respectively (70% increase). *C. capitata* numerically dominates benthic species abundance at more than five sites currently sampled (nine in total).
Fish		
	Maintain species composition at 35 – 40 % estuary-associated marine species, 20 % non-dependent marine species 45 – 50 % indigenous freshwater species. All numerically dominant species are represented by 0+ juveniles. The overall dominant species *Liza richardsonii* should not drop below 90 % biomass.	Non estuary associated marine or freshwater species become proportionally dominant. 0+ juveniles do not recruit, *L. richardsonii* < 90 % biomass.
Birds		
	The estuary should contain a rich avifaunal community that includes representatives of all the original groups, significant numbers of migratory waders and terns, as well as a healthy breeding population of resident waders. The estuary should support over 8,000 waterbirds in summer and over 6,000 birds in winter.	Bird numbers should not continue on a downward trajectory. The five-year average numbers of the 14 species for which the estuary supports more than 1% of the southern African or global population should not fall to below half of the

Component	
EcoSpecs	***TPCs***
	average numbers reported by Anderson et al. (2003): Blacknecked Grebe 125 Great White Pelican 473 Cape Cormorant 984 Lesser Flamingo 1,031 Greater Flamingo 700 South African Shelduck 516 Cape Shoveller 373 Chestnutbanded Plver 97 Pied Avocet 891 Curlew Sandpiper 1,666 Kelp Gull 1,098 Hartlaub's Gull 707 Caspian Tern 165 Swift Tern 344 Damara Tern 58

1 Microphytobenthos

10. Orange River Estuary: Monitoring programme

The accuracy with which the ecological status of any estuary can be determined largely depend on the amount of available data (i.e. existing data and information, particularly historical data), additional data that could be collected within time/budget constraints and the complexity of processes in a particular estuary.

The Orange Estuary has sufficient data to inform a medium confidence study. Long-term monitoring would assist in increasing the overall confidence.

The monitoring programme is illustrated in Table 34.

Table 34. Orange Estuary: Monitoring programme

Indicator / ***Monitoring action***	***Temporal scale (frequency and timing)***	***Spatial scale***
Hydrology		
Measure freshwater inflow into estuary.	Continuous.	Vioolsdrift (D8H003) and Brand Kaross.
Hydrodynamics		
Record water levels in the Estuary.	Continuous.	At bridge and mouth.
Hydrodynamics		
Aerial/satellite photographs of estuary (preferably on spring low).	Every 3 years.	Entire estuary up to Brand Kaross.
Sediment dynamics		
Bathymetric surveys: Series of cross-section profiles at fixed 500 m intervals and a longitudinal profile collected, but in more detail in the mouth area (every 100 m). The vertical accuracy should be about 5 cm. Set sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content.	Every 3 years.	Entire estuary.
Water quality		
Collect data on conductivity, temperature, suspended matter/turbidity, DO, pH, inorganic nutrients and organic content in river inflow.	Monthly continuous.	At river inflow.
Assess and better quantify wastewater input (e.g. nutrients and organics) from diffuse sources (e.g. caravan park, waste water treatment works).	Once-off detailed. Possibly long-term (e.g. peak seasons) if input remains significant (preferably these should	In stream (source/s).

Indicator Monitoring action	*Temporal scale (frequency and timing)*	*Spatial scale*
	be mitigated).	
Record longitudinal salinity and temperature profiles (and any other in situ measurements possible e.g. pH, DO, and turbidity).	Seasonally, every year.	Entire estuary (10 stations).
Take water quality measurements along the length of the estuary (surface and bottom samples) for system variable (pH, DO, suspended solids/turbidity) and inorganic nutrients in addition to the longitudinal salinity and temperature profiles.	Seasonal surveys, every 3 years or when significant change in water inflows or quality expected.	Entire estuary (10 stations).
Microalgae		
Phytoplankton: Conduct water column chl-a measurements and counts of dominant phytoplankton groups (incl. flagellates, diatoms, dinoflagellates, chlorophytes and cyanobacteria).	Survey during normal flows, ideally late summer (20 – 50 m^3/s), every 3 years.	Entire estuary (min. 5 stations).
Benthic microalgae: Conduct intertidal and subtidal benthic chl-a measurements.		
Macrophytes		
Field assessments and comparative analysis (see section 10.5).	Summer survey every 3 years.	Entire estuary.
Invertebrates		
Record species and abundance of zooplankton, based on samples collected across the estuary at each of a series of stations along the estuary. Record benthic invertebrate species and abundance, based on subtidal and intertidal core samples at a series of stations up the estuary, and counts of whole densities. Measures of sediment characteristics at each station.	Summer and winter survey every 3 years.	Entire estuary (5 stations).
Fish		
Record species, abundance and size composition of fish, based on seine-net and gill net sampling.	Summer and winter survey every 3 years.	Entire estuary (10 stations) and 5 stations in first 10 km of freshwater reaches.
Birds		
Full count of all water associated birds, covering as much of the estuarine area as possible, from a boat and on foot (this is also part of the requirements of Ramsar).	Summer and winter survey every year; with count as close to spring low tide as possible.	Entire estuary (in counting sections).

10.1 Hydrology and hydrodynamics

Hydrology and hydrodynamics are monitored to determine if the primary physical processes that drive the conditions of the estuary are being .maintained or achieved. This type of data set can also serve as an early warning system that can highlight a decline in ecosystem condition before a decrease in the biologic health is observed.

Continuous water level recordings: A continuous water level recorder should be installed at the mouth of the estuary in addition to the existing water level recorder at the bridge. Where possible, daily mouth observations should be logged in temporarily open/closed estuaries and particularly in systems with the semi-closed mouth phase. The time at which the observation was made and the state of the tide must also be recorded, ideally at low tide.

Continuous flow recording of river inflow: A flow gauging station should be maintained to measure river inflow to the Orange Estuary.

Aerial/satellite photographs: Full colour geo-referenced rectified photographs ~1: 5 000 scale covering the entire estuary based on the geographical boundary preferably at low tide in summer i.e. similar to those for macrophyte surveys. The image must include the breaker zone near the mouth.

Technical Report 33, chapter 2 provides detailed examples of how the hydrology and hydrodynamics data should be analysed.

10.2 Sediment dynamics

The disturbance of the sediment erosion/deposition equilibrium in an estuary can lead either to siltation, resulting in the estuary becoming shallower, or it can lead to the erosion of important sediment habitats. Under natural conditions estuaries are generally in a state of long-term equilibrium of sedimentation and erosion. However, this equilibrium can be disturbed because of changes in run-off, especially if the occurrences and magnitudes of major floods are changed.

Floods and high seasonal flows influence the sediment erosion/deposition equilibrium in the Orange Estuary. Floods can alter important features within an estuary, such as the bathymetry (e.g. channel depth or the size of intertidal areas) and sediment composition (e.g. sand or mud) and may require additional ad hoc sampling to determine their influence.

Suitable sediment data records cannot be acquired in the short term. Therefore, if sediment processes are to be better quantified, a long-term programme will have to be implemented.

Technical Report 33, chapter 2 provides detailed examples of how the sediment data should be analysed.

10.3 Water quality

Estuaries receive water from two sources, i.e. the river and sea, each with distinctively different water quality characteristics, particularly in terms of system variables and nutrients. In turn, the water quality characteristics along the length of an estuary depend on the extent of the influences of each of these sources (governed by hydrodynamic processes), as well as biochemical processes (e.g. organic degradation and eutrophication) taking place at that point within the estuary. The influence of biochemical processes is particularly evident where residence times of water are longer, for example along the middle reaches of an estuary during the low flow season. It is therefore also crucial that water samples in the two sources, i.e. river and sea be taken.

Water quality samples in the river inflow needs to be taken near the head of the estuary (e.g. at Brand Kaross) in order to measure system variables (pH, DO, turbidity, suspended solids, total dissolved solids and temperature), nutrients (inorganic nitrogen [nitrite, nitrate and ammonia], reactive phosphate and silicate) and toxic substances.

Water quality in the estuary should be measured at 10 stations distributed geographically along the entire estuary at fixed intervals. A sampling station is defined as a location at a specific 'distance from the mouth'. The following samples should be collected:

- salinity and temperature profiles (also required for hydrodynamics);
- system variables (pH, DO (mg/ℓ and % saturation), turbidity/suspended solids/Secchi disc depth);
- inorganic nutrients (nitrate/nitrite, ammonia, reactive phosphate and reactive silicate).

Salinity and temperature data must be collected at 0,5 m depth intervals, while other water quality parameters are collected in surface and bottom waters. At stations deeper than 2 m, a sample at an intermediate depth may also be required (site specific decision).

For long-term monitoring programmes, water and sediment quality data are particularly important for the interpretation of specific biological responses and, therefore must be collected along with the relevant biotic components as indicated during their sampling surveys.

The analytical techniques used in the processing of marine and estuarine water quality samples vary greatly from those used in the analysis of fresh water samples. It is therefore crucial that an accredited marine analytical laboratory conducts the analyses of water quality samples.

Technical Report 33, chapter 2 provides more detailed examples of how the water quality data should be collected and analysed.

10.4 Microalgae

Microalgae is used in long-term monitoring to indicate whether there is a functional river-estuary interface. Microalgae is also be used effectively in long-term monitoring as an indicator of water quality problems.

Phytoplankton: To estimate phytoplankton biomass, collect duplicate samples for chlorophyll-a at the surface and at 0,5 m depth intervals. Use a spectrophotometer for sample analysis before and after acidification. Do cell counts (at 400X magnification) on dominant phytoplankton species to establish species distribution and composition, i.e. green algae, flagellates, dinoflagellates, diatoms and blue-green algae.

Benthic microalgae: Collect intertidal and subtidal benthic samples for chlorophyll-a (biomass) analysis. Collect five samples at each station. Analyse samples using a recognised technique, e.g. HPLC. Record the relative abundance of dominant algal groups, i.e. green algae, dinoflagellates, diatoms and blue-green algae and identify the dominant species.

At each station also measure:

- water salinity and inorganic nutrients;
- sediment particle size distribution and organic content;
- light penetration (photosynthetically active radiation) or Secchi disk depth.

Combining water and sediment quality surveys on a particular estuary with the microalgal survey does this most cost-effectively. The temporal scale of the microalgal sampling needs to match that of the invertebrates (zooplankton) to link the response patterns of these biotic components as best as possible.

Technical Report 33, chapter 3 provides additional information of where and how the microalgae data should be collected and how it should be analysed.

10.5 Macrophytes

The following information needs to be captured from recent aerial photographs and ortho-photographs covering the entire estuary as defined by the geographical boundaries, including:

- the number of different habitats (plant community types);
- the area covered by each plant habitat;
- any historical change in area covered by plant habitat;
- the extent of anthropogenic impacts (agriculture, flood plain development).

Field data need to be collected for ground-truthing of aerial photographs:

- the number of different plant habitats (plant community types);
- the area covered by each plant habitat;
- a species list for each plant habitat;
- the extent of anthropogenic impacts such as grazing, trampling, alien vegetation, boating, bait digging.

Permanent transects (sampling stations) need to monitoring of changes in plant habitats. Along each transect (minimum of four) the following data need to be collected:

- elevation profile and water level;
- water column salinity and turbidity;
- sediment salinity, moisture content and sediment composition.

The following monitoring actions must be undertaken:

- survey of main channel to assess status of macroalgae and submerged macrophytes;
- ground-truth maps to update the map produced for 2012 and check the areas covered by the different macrophyte habitats;
- record number of macrophyte habitats, identification and total number of macrophyte species, number of rare or endangered species, or those with limited populations documented during a field visit;
- assess extent of invasive species in the estuarine area;
- record percentage plant cover, sediment salinity and sediment moisture content on a series of permanent transects (Transects 1–3) along an elevation gradient;
- take measurements of depth to water table and ground water salinity in supratidal marsh areas along the three permanent transects.

Technical Report 33, chapter 4 provides additional information of where and how the macrophyte data should be collected and how it should be analysed.

10.6 Invertebrates

Zooplankton: Collect quantitative samples after dark, preferably during neap tides (mid to high tide), because currents are less strong and zooplankton will be more active in the water column. Sampling should be done at mid-water level, i.e. not at the surface. Two net trawls (WP 2 – 200 micron mesh) representing two replicate samples should be taken at each station. The net should be pulled for three minutes per station (10,0 – 12,0 m^3 of water) at 0,15 knots diagonally across the estuary at each site. Record the abundance (density per volume) of each species in each trawl and average the results over the two replicates for each station. At each station phytoplankton samples (i.e. water column sample) and benthic microalgae samples need to be collected for chlorophyll-a analyses.

Benthic invertebrates: Collect (subtidal) samples using a Zabalocki-type Eckman grab sampler with six to nine randomly placed grabs (replicates) at each station. Collect intertidal samples at spring low tide using a core sampler with a minimum diameter of 150 mm and depth of 250 mm, with six to nine replicates at each site along the transect. Grab/core sample should then be placed in a 500–micron sieve bag and the contents gently sifted so as to remove fine particles. Animals and any other relatively coarse material are then stored in formalin for identification in the laboratory. At least six replicates are required per station. For intertidal benthic invertebrates that are not well quantified by core sampling (e.g. mud prawns, sand prawns, some crabs), count overall density for each species in 0,25m^2 minimum quadrat areas, with five replicates at each station.

The following must be completed at each site:

- identify fauna to the lowest taxon possible;
- record animal density and species abundance (animals per m^2);
- record the presence of *Zostera* or other macrophytes at the site.

At each station, sediment samples need to be collected for particle size analysis (250 ml) and organic content (250 ml) using standard techniques. Other parameters that must be measured at each site are temperature, salinity, oxygen, conductivity, turbidity, chlorophyll-a and pH. Measurements should be taken at the surface, 0,5 m, 1,0 m from the surface and thereafter at 1,0 m depth intervals.

Macrocrustaceans: Quantitative sampling for macrocrustaceans should be conducted during neap tides (mid to high tide), at the same stations used for zooplankton. Use a benthic sled (80 cm x 80 cm, with a 500 micron mesh) attached to a flow meter to collect the sample; tow for 30 metres diagonally across the estuary. Take two samples at each station. Set two prawn/crab traps per station overnight (more applicable to sub-tropical areas).

Identify fauna to the lowest taxon possible. Record the number of species and determine densities for each species. A sampling station is defined as a specific location in the estuary (at a specific 'distance from the mouth') from where a number of replicates are collected.

For invertebrate surveys, seven sediment grain size categories should be used, ranging from mud to very coarse sand. Each category relates to a particular size diameter in the following manner:

- >2 mm: Very coarse sand;
- 2 – 1 mm: Very coarse sand;
- 1 – 0,5 mm: Coarse sand;
- 0,5 – 0,25 mm: Medium sand;
- 0,25 – 0,125 mm: Fine sand;
- 0,125 – 0,0625 mm: Very fine sand;
- <0,0625 mm: Mud (silt and clay).

The percentage organic content of sediments can roughly be classified as:

- <0.5%: Very low;
- 0.5 – 2%: Low;
- 1 – 2%: Moderately low;
- 2 – 4%: Medium;
- > 4%: High.

Water (salinity, temperature, pH, DO and turbidity) and sediment quality (sediment grain size and organic content) measurements need to also be collected during the invertebrate surveys. Combining water and sediment quality surveys on a particular estuary with the invertebrate surveys does this most cost-effectively.

Technical Report 33, chapter 5 provides additional information of where and how the invertebrate data should be collected and how it should be analysed.

10.7 Fish

The primary goal of fish sampling is to obtain species and size composition of the fish present in the system. Conduct fish surveys using seine nets and gill nets as primary gear, but non-destructive sampling should be practiced where possible. The survival rate of larger fish is much greater if they are removed from a gill net by cutting the mesh (easily repaired afterwards) whereas most seined fish can be measured and released alive. If there are abundant fish in a sample, 100 individuals of a species should be measured, the rest counted and released. However, it must be accepted that some fish, especially clupeids, die very easily.

Seine nets: 30 m x 2 m x 15 mm multifilament bar mesh in the wings and a 5 mm bar mesh in the purse. Seine-nets should be 30 m long by 2 m depth. The cod end (bag, purse) and the wings 5 m either side of it should be 5 mm bar whereas the remaining 15 m of each wing can be 15 mm bar mesh. This is required to adequately sample estuarine and 'faster moving' marine species. The net should be weighted such that it sinks below the surface when set in water deeper than 2 m (i.e. the distance between the lead and cork lines). A light net makes it more difficult to obtain a representative sample from weed and sandy areas, e.g. flatfish species tend to burrow in the sand and escape under a light seine.

Gillnets: Monofilament gill nets should comprise at least three different mesh sizes within the range 40 – 50 mm stretch mesh. Monofilament gill nets should comprise at least four nets (or panels) of which one net comprises 44, 48, 51 and 54 mm mesh, plus three more nets in the 75 – 150 mm stretched mesh range (e.g. 75, 100 and 145 mm stretched mesh).

Water quality measurement (salinity, temperature and other physico-chemical properties) need to be collected during the fish surveys. Combining water quality surveys on a particular estuary with the fish surveys does this most cost-effectively.

Technical Report 33, chapter 6 provides additional information of where and how the fish data should be collected and how it should be analysed.

10.8 Birds

Undertake full bird counts of all water-associated birds. First, divide the estuary into counting sections on the basis of habitat type as delineated in Anderson et al. 2003 and Technical Report 33, and taking into account the area that can be covered per counter during a low tide period.

For each counting session capture the following information:

- a species list;
- the number of birds of each species (at low tide);
- the state of the habitat at the time of observation (or take a photo of site);
- the levels of human disturbance at time of counting;
- take note of key areas for feeding, roosting and breeding on the estuary and adjacent floodplain;
- take note of and count high tide aggregations of feeding or roosting birds as far as possible;
- take note of breeding areas and count breeding aggregations as far as possible;
- the state of the mouth must be recorded at each count.

The upper boundary of the study area is the same as that for the overall study, i.e. the upper geographical boundary of the estuary. The seaward boundary, which is regularly crossed by seabird species such as cormorants, gulls and terns, is most difficult to define. As a guideline, it should include the full tidal delta area and sand bars up to the back line of breakers outside the estuary mouth.

Technical Report 33, chapter 7 provides additional information of where and how the bird data should be collected and in what manner it should be analysed.

11. Recommendations

11.1 Orange and Fish rivers: Baseline and additions

The surveys undertaken during June 2012 serve as the baseline. However, some additions are required to improve the baseline. The existing baseline is summarised in Table 35 and the additional work is required to improve the confidence in the baseline is also provided.

Table 35 Rivers: Existing baseline survey data and additional recommendations to support the baseline information

Component	***Baseline survey***	***Temporal scale***	***Spatial scale***
Existing baseline			
Geomorphology	Aerial photography. Baseline survey (linked to hydraulic surveys).	Jun 2012.	EFR Fish 1, Fish 2, O5
Water quality	Available monitoring data.	Varied.	All WQ monitoring stations.
Diatoms	Diatom collection.	Jun 2012. 2009, 2010, Jun 2012. 2008, 2009, Jun 2012.	EFR Fish 1, Ai-Ais EFR Fish 2 EFR O5
Riparian vegetation	Riparian vegetation survey.	Jun 2012.	EFR Fish 1, Fish 2, O5
Fish	Electrofishing.	Jun 2012.	EFR Fish 1, Fish 2, EFR Ai-Ais, O5
Macro-invertebrates	NASS2 and SASS5 surveys.	Jun 2012. 2010, Jun 2012. 1995, 2004, 2010, Jun 2012	EFR Fish 1, Ai-Ais EFR Fish 2 EFR O5
Additional to existing baseline			
Water quality	Additional salinity, DO and temperature measurements to be added to baseline (prior to Neckartal Dam construction)	Continuous (loggers).	EFR Fish 1, Fish 2
	All water quality measurement.	Continuous loggers and link to ESIA monitoring.	EFR Ai-Ais (new quality site)

Component	*Baseline survey*	*Temporal scale*	*Spatial scale*
Diatoms	Diatom collection (linked to water quality measurements prior to Neckartal Dam construction).	At least two dry season and wet season sampling.	EFR Fish 2
Fish (see info below table)	Electrofishing.	One dry season survey.	EFR Fish 1 EFR Fish 2 EFR Ai-Ais

It is strongly recommended that an additional baseline fish survey should be done at the Fish River EFR sites during the late dry season to evaluate the conditions when only isolated pools (no flow) is present. This would provide an indication of the status of the fish assemblage when they have been stressed and exposed to extreme conditions (high salinity, high temperatures and temperature fluctuations, etc.). It can be expected that conditions will vary between seasons, as well as between years in any system, and especially in a seasonal system like the Fish River. The more complete and diverse the baseline data is, the more likely the chances of detecting anthropogenic induced changes over time. It is furthermore advised that the additional baseline survey should be done prior to the finale construction of the Neckartal Dam.

11.2 Orange Estuary: Baseline and additions

The surveys undertaken during January and June 2012 serve as the baseline. However, some additions are required to improve the baseline. The existing baseline is summarised in Table 36 and the additional work required to improve the confidence in the baseline is also provided.

Table 36 Orange Estuary: Existing baseline survey data and additional recommendations to support the baseline information

Component	*Baseline survey*	*Temporal scale*
Existing baseline		
Hydrology	Existing flow records.	Vioolsdrift 1935 to 2012
Hydrodynamics	Continuous water level recordings.	At the bridge
	Aerial photographs of estuary.	1937, 1943, 1951, 1962, 1964, 1976, 1977, 1979, 1980, 1987, 1988, 1990
Sediments	Series of cross-section profiles along the along the entire estuary.	Partial: 1987, 1988, 1990
	Series of sediment grab samples.	Partial: 1988, 2008
	Sediment load near the head of estuary.	Upstream 1988
Water quality	Monthly river water quality measurements on system variables.	Available Ernst Oppenheimer Bridge and Vioolsdrift
	Longitudinal salinity and temperature profiles (in situ).	Feb 2004, Aug 2004, Feb 2005, Feb 2012, Aug 2012
	Longitudinal DO, pH and turbidity	Jan 1979, Sep 1993, Feb, Aug

Component	*Baseline survey*	*Temporal scale*
	measurements.	2004, Feb 2005, Feb, Aug 2012.
	Longitudinal inorganic nutrients	Jan 1979, Feb 2012 and Aug 2012
	Organic content and toxic substances.	Trace metal in sediment (1979)
Microalgae	Chlorophyll-a measurements.	Aug 2012
Invertebrates	Benthic, hyperbenthic, zooplankton samples from survey. Organic content from sediment.	2004, 2005 and 2012
Fish	Fish surveys (gill nets and seine-nets).	1959, 1981, 1984, 1986, 1990, 1997, 1998, 2004, 2005 and 2012
Birds	Bird survey	1985, 1986, 1994, 1995, 1999, 2003, 2012
Additional to existing baseline		
Hydrology	Improve on estimates for river inflow.	1993–1996
Hydrodynamics and Macrophytes	Lidar survey up to the 5 m MSL contour.	Once off
Sediments	Sediment core samples along the entire estuary (10 – 20 m deep). Sample suspended sediment load at Vioolsdrift.	Once off Daily for at least three years
Invertebrates	Sampling to account for the seasons. Recruitment survey.	Four times in one year During mass migration (once off)
Fish	Sampling (including adjacent surfzone 1 km either side of mouth) to account for the seasons. Includes stomach content analysis.	Four times in one year

11.3 Specific studies

This refers to studies (once-off) that are required to address identified gaps in the understanding of the system functioning.

Research recommendations are linked to three activities, i.e. (1) an attempt to verify and identify the source of nutrients in the system around and south of Neckartal Dam and between Vioolsdrift and the Orange Estuary, (2) to verify metal peaks evident from the existing water quality data, and (3) to establish if there are any toxic substances accumulating in the Orange Estuary.

Nutrient assessment programme: The programme will have two objectives.

1. The programme will aim to identify the sources of nutrients downstream of Hardap Dam irrigation, to identify hotspots and to establish reference conditions for TIN and phosphate. Sources will be identified by investigating the possibility of nutrient peaks via microbial remineralization, and checking links between geology and nutrient levels to determine the possible influence of the geology of the area. The TIN and phosphate reference conditions can possibly be identified by monitoring a site upstream of Hardap Dam.

2. In the lower Orange River a comparison between and the Vioolsdrift (D8H083Q01) and the Sir Ernest Oppenheimer Bridge (D8H012Q01) water quality stations indicate a significant increase in nutrient input below Vioolsdrift. As irrigated agriculture are predominantly concentrated in three areas along this stretch of the river, it is recommended that a few shallow boreholes be installed and monitored in the banks adjacent to these potential hotspots to try and identify the source and/or mechanism of the nutrients. Once the source has been identified, mitigation measures must be developed in consultation with the local famers and an agricultural specialist to reduce the input to the estuary.

Metal verification programme: Some metals levels were elevated in the river during particular months of monitoring. The validity and source of these peaks must be investigated as follows:

- monitor monthly data to determine if peaks were valid or are anomalies;
- if peaks are confirmed, check links between surface water and groundwater in the area, to assist in determining possible natural geological origins;
- adapt and continue monitoring as required.

Toxin verification programme in the Orange Estuary: No sampling was done for toxic substances (e.g. trace metals, hydrocarbons, herbicides and pesticides) in the Orange Estuary during this study. It is therefore recommended that sediment samples be collected and analysed for toxic substances (i.e. trace metals, petroleum hydrocarbons, herbicides and pesticides). To assist with the interpretation of results, samples should also be analysed for sediment grain size distribution and organic content. A grid of sediment sampling stations should be selected across the estuary, specifically targeting depositional areas (characterised by finer sediment grain sizes and/or higher organic content).

11.4 General recommendations

11.4.1 Macro-invertebrates

The use of mini-SASS monitoring is recommended for more frequent (annual) assessment of conditions in the lower Orange River. Details of mini-SASS are described by Graham et al. (2004). The method is a simplified version of SASS that can be implemented by non-specialists, yet the method provides comparable results to the full SASS method.

11.4.2 Governmental water quality and hydrology monitoring

Any monitoring programme that needs to interpret the responses of biota in terms of habitat changes are dependent on using the standard hydrology and water quality continuous monitoring data. This data is currently undertaken by the South African DWA. Some of the physico-chemical variables that are important for ecological monitoring are not measured. As part of the DWA Resource Quality Services Directorate's River Health Programme initiative, loggers measuring water quality parameters not measured as a standard by DWA have been installed at gauging weirs. The parameters that are measured are pH, temperature, EC and in some case, DO. These loggers measure at regular intervals (e.g. 20 minutes) and are linked to the DWA internet (pers. comm. CJ Kleynhans). It is recommended that as part of this initiative, these loggers be installed at the Vioolsdrift gauging weir (D8H003) and at the Sendelingsdrift weir which is under construction. A request from ORASECOM should be made to DWA for this monitoring to be included as part of the standard DWA monitoring.

11.4.3 Initiation of monitoring programme

The monitoring programme should be initiated as soon as possible and prior to the construction (with specific reference to disturbance of the river) of Neckartal Dam. If a long period occurs between the baseline and the start of the programme, the baseline might need to be re-established if other developments have taken place in the catchment.

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Appendix A Visual assessment of the Fish River condition

A.1 Introduction and objectives

Monitoring ecological conditions in seasonal systems, such as the Fish River, is difficult because of the naturally high variability in river conditions. Furthermore, the remote location of the Fish River, and limited capacity of the regional Parks and Wildlife Agency, called for a cost-effective yet reliable method for assessing the ecological state of the Fish River. A simple visual method was therefore developed, mainly for use by regulatory agencies. The method was intended to complement more detailed assessment by specialists that would take place less frequently. The proposed method for monitoring overall ecological conditions in the Fish River comprises frequent (annual) visual assessment of eight key parameters that were identified by specialists in a workshop discussion.

The objective of the visual assessment of river conditions was to provide an early warning of significant changes in ecological conditions that could trigger appropriate mitigation measures to address detrimental impacts before changes become irreversible or seriously damaging to ecosystem structure and/or function.

A.2 Methodology

The visual assessment of river condition comprises eight key parameters, each of which was weighted in terms of its importance in defining overall river condition, with the weightings expressed as a percentage. Weightings were based on professional judgement, with highest weightings allocated to the condition of pools (40%), salinity (13%) and fish kills (12%). Zero weighting was allocated to flow conditions, which simply means that flow conditions are recorded, but have no influence on the score.

At each site to be assessed, each parameter is rated in terms of the extent to which it has changed from a hypothetical optimal state, where 0 = *Optimal*; 1 = *Sub-Optimal*; 2 = *Marginal*; 3 = *Poor*. An overall score of River Condition is calculated from the sum of each weighted parameter multiplied by the rating, and expressed as a percentage, where 100% = All parameters Optimal. A simple colour-coded warning system is used to classify each parameter, whereby:

- green = rating of zero or one (Optimal and Sub-optimal): no mitigation action is needed;
- yellow = rating of two (*Marginal*): Yellow Card Warning is triggered;
- red = rating of three (*Poor*): Red Card triggered, so mitigation action is needed.

Summary results are presented by indicating the number of parameters in each of the three colour codes.

A.3 Data sheet and photo guide

A proposed data sheet for visual assessment of the Fish River, which is to be used during a field assessment, is provided below. A photo guide is provided and serves as a general guide to rating the parameters at the time of sampling. This proposed data sheet and photo guide is also provided electronically.

Visual assessment of river condition: Fish River

River Name:	Project:
Site No.:	Site Location:
Latitude:	Catchment:
Longitude:	Land-user:
Assessor(s):	Date:

Parameter	***Rating (0-3)***	***Weight (%)***	***=(A/3)*B***	***Optimal***	***Sub-optimal***	***Marginal***	***Poor***
	A	***B***		***0***	***1***	***2***	***3***
1. Flow	0	0	0.0	Noisy	Babbling	Quiet	Dry
2. Pools	0	40	0.0	Pools full	Pools not full but >0.5 m	Pools not full but <0.5 m	One or more pools dry
3. Benthic algae	0	10	0.0	<10%	10-49%	50–80%	>80%
4. Salinity	0	13	0.0	Absent	Slight	Moderate	Critical
5. *Phragmites* reeds	0	10	0.0	<10%	10–49%	50–80%	>80%
6. Gomphid tracks	0	10	0.0	Abundant	Common	Rare	Absent
7. Fish	0	12	0.0	Fish common	Fish present or not seen	Dead fish present	Major kill
8. Phytoplankton	0	5	0.0	Absent (clear)	Slight to moderate	High	Critical (Green)
			100%	**Actions needed:**			
Category:			**A**				

Summary Results

(green)	Natural
(yellow)	Warning
(red)	Red card (action needed)

Parameter	*Optimal (0)*	*Sub-Optimal (1)*	*Marginal (2)*	*Poor (3)*
1. Flow	 Noisy	 Babbling	 Quiet	 Dry
2. Pools	 Pools full	 Pools not full but >0.5 m deep	 Pools not full but <0.5 m deep	 One or more pools dry
3. Benthic algae	 <10%	 10 – 49%	 50 – 80%	 >80%

Parameter	***Optimal (0)***	***Sub-Optimal (1)***	***Marginal (2)***	***Poor (3)***
4. Salinity	 Absent	 Slight	 Moderate	 Critical
5. *Phragmites* reeds	 <10%	 10 – 49%	 50 – 80%	 >80%
6. Gomphid tracks	 Abundant	 Common	 Rare	 Absent

Parameter	*Optimal (0)*	*Sub-Optimal (1)*	*Marginal (2)*	*Poor (3)*
7. Fish	 Fish common	 Fish present or not seen	 Dead fish present	 Major kill
8. Phytoplankton	 Absent (Clear)	 Slight to Moderate	 High	 Critical (Green)