REPORT NUMBER: RDM/WMA06/00/CON/COMP/0217

PROJECT NUMBER: WP 10974

DETERMINATION OF ECOLOGICAL WATER REQUIREMENTS FOR SURFACE WATER (RIVER, ESTUARIES AND WETLANDS) AND GROUNDWATER IN THE LOWER ORANGE WMA

ECOLOGICAL SPECIFICATIONS AND MONITORING REPORT

water & sanitation
Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

JULY 2017

DETERMINATION OF ECOLOGICAL WATER REQUIREMENTS FOR SURFACE WATER (RIVER, ESTUARIES AND WETLANDS) AND GROUNDWATER IN THE LOWER ORANGE WMA

ECOLOGICAL SPECIFICATIONS AND MONITORING REPORT

Report Number: RDM/WMA06/00/CON/COMP/0217

JULY 2017

REFERENCE

This report is to be referred to in bibliographies as:

Department of Water and Sanitation, South Africa, July 2017. Determination of Ecological Water Requirements for Surface water (river, estuaries and wetlands) and Groundwater in the Lower Orange WMA. Ecological Specifications and monitoring report. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. DWS Report No: RDM/WMA06/00/CON/COMP/0217.

DOCUMENT INDEX

Index Number	DWS Report Number	Report Title
1	RDM/WMA06/00/CON/COMP/0115	Inception report
2	RDM/WMA06/00/CON/COMP/0116	Resource Unit report
3	RDM/WMA06/00/CON/COMP/0216	River EWR report
4	RDM/WMA06/00/CON/COMP/0316	Buffels, Sout, Swartlintjies, Spoeg, Groen Estuary EWR report
5	RDM/WMA06/00/CON/COMP/0416	Groundwater EWR report
6	RDM/WMA06/00/CON/COMP/0516	BHNR report
7	RDM/WMA06/00/CON/COMP/0616	Wetland EWR report
8	RDM/WMA06/00/CON/COMP/0117	Report on consequences of scenarios
9	**RDM/WMA06/00/CON/COMP/0217**	**Ecological specifications and monitoring report**
10	RDM/WMA06/00/CON/COMP/0317	Main Summary report
11	RDM/WMA06/00/CON/COMP/0417	Close-out report
12	RDM/WMA06/00/CON/COMP/0517	Electronic data

DEPARTMENT OF WATER AND SANITATION

CHIEF DIRECTORATE: WATER ECOSYSTEMS

DETERMINATION OF ECOLOGICAL WATER REQUIREMENTS FOR SURFACE WATER (RIVER, ESTUARIES AND WETLANDS) AND GROUNDWATER IN THE LOWER ORANGE WMA

ECOLOGICAL SPECIFICATIONS AND MONITORING REPORT

Approved for RFA by:

……………………………………..

Delana Louw
Project Manager

……………………………………..

Date

DEPARTMENT OF WATER AND SANITATION (DWS)
Approved for DWS by:

……………………………………..

Chief Director: Water Ecosystems

……………………………………..

Date

ACKNOWLEDGEMENTS

The following persons contributed to this report:

Authors	Company
Deacon, Andrew	Private
Louw, Delana	Rivers for Africa eFlows Consulting (Pty) Ltd.
Koekemoer, Shael	Koekemoer Aquatic Services
Kotze, Piet	Clean Stream
Mackenzie, James	Mackenzie Ecological and Developmental Services
Mare, Manie	WRP
Sami, K.	WSM Leshika Consulting Pty (Ltd)
Scherman, Patsy	Scherman Colloty and Associates
van Niekerk, L	CSIR

Report editor: Shael Koekemoer

REPORT SCHEDULE

Version	Date
First draft	26 July 2017
Final	23 August 2017

EXECUTIVE SUMMARY

BACKGROUND

The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) initiated a study for the provision of professional services to undertake the 'Determination of Ecological Water Requirements for Surface Water (Rivers, Estuaries and wetlands) and Groundwater in the Lower Orange Water Management Area (WMA). Rivers for Africa was appointed as the Professional Service Provider (PSP) to undertake this study.

PURPOSE OF REPORT

The purpose of this report is to document the Ecological Specifications (EcoSpecs) and Threshold of Potential Concern (TPC) and provide input towards a monitoring plan and implementation of the Reserve.

ECOSPECS IN CONTEXT OF THE PRELIMINARY ECOLOGICAL RESERVE CATEGORY (PERC)

EcoSpecs relate to the ecological objectives in terms of the Ecological Category associated with the Preliminary Reserve. It follows therefore that prior to determining EcoSpecs, a decision is required regarding the scenarios to be selected and the Preliminary Reserve and associated Ecological Category. The Ecological Category linked to the Preliminary Reserve is referred to as the Preliminary Ecological Reserve Category (PERC). As the REC cannot always be met, the PERC represents the realistic Ecological Category that will be signed off. The PERC may be the REC, or any other category that is attainable.

The PERC is summarised below:

Rivers: EWR Site	PES	REC	PERC
O3	C	B	B/C
O4	C	B/C	B/C
O5	B/C	B	B
Estuaries	**PES**	**REC**	**PERC**
Orange Estuary	D	C	C/D
Buffels	D	D	D
Swartlintjies	B	B	B
Spoeg	A/B	A/B	A/B
Groen	B	A/B	A/B
Sout	E	D	D/E→D

ECOSPECS, TPCs AND MONITORING

EcoSpecs are biological specifications that are numerical values or narrative statements that define a desired biological condition (Ecological Category). They indicate the level of habitat integrity that is required to attain a specific biological condition for the river and therefore provides the ecological detail that characterises the Ecological Category. For a Preliminary Reserve, it would be the biological conditions relating to the Preliminary Ecological Reserve Category (PERC). EcoSpecs must be quantifiable, measurable, verifiable and enforceable and ensure protection of all components. TPCs indicate the numerical values around the EcoSpecs that, if approached, would initiate more detailed investigations or even management actions. TPCs are therefore upper and lower levels along a continuum of change.

Ecological monitoring is the collection and analysis of repeated observations or measurements to evaluate change in the condition of the resource and the progress towards meeting the management objective (Elzinga *et al.,* 1998). As used with DWS, it is the measurement of EcoSpecs to determine if the PERC is attained (Kleynhans *et al.,* 2009). The PES acts as the baseline against which change is monitored.

EWR O3: ECOSPECS

The PERC for the components for which EcoSpecs are set are provided below. Note that the estimated changes for the EcoSpecs associated with a post dam development scenario are also provided.

EWR O3: PERC

Driver components	PES	REC	Pre-Dam recommendation PERC (Sc A2; A3)	Post-Dam recommendation D Scenarios*
Physico chemical	C	C	B/C	B
Fish	C	B	B/C	B
Macroinvertebrates	C	B	B/C	B/C
Riparian vegetation	B/C	B	B/C	B/C
EcoStatus	C	B	B/C	B/C

* Further investigations are necessary on dam sizes to finalise the post-dam scenario recommendations. However, as the differences between the D and C Scenarios are relatively small, an indication of EcoSpecs and TPCs associated with the D scenarios (small dam) has been provided. This will be updated during the Classification study that will folllow.

EWR O4: ECOSPECS

The PERC for the components for which EcoSpecs are set are provided below. Note that the estimated changes for the EcoSpecs associated with a post dam development scenario are also provided.

EWR O4: PERC

Driver components	PES	REC	Pre-Dam recommendation PERC (Sc A2; A3)	Post-Dam recommendation D Scenarios*
Physico chemical	C/D	C/D	C	C
Fish	C	B/C	C	B/C
Macroinvertebrates	C	B/C	B/C	B/C
Riparian vegetation	C	B	B/C	B/C
EcoStatus	C	B/C	B/C	B/C

* Further investigations are necessary on dam sizes to finalise the post-dam scenario recommendations. However, as the differences between the D and C Scenarios are relatively small, an indication of EcoSpecs and TPCs associated with the D scenarios (small dam) has been provided. This will be updated during the Classification study that will folllow.

EWR O5: ECOSPECS

The PERC for the components for which EcoSpecs are set are provided below. Note that the estimated changes for the EcoSpecs associated with a post dam development scenario are also provided.

EWR O5: PERC

Driver components	PES	REC	Pre-Dam recommendation PERC (Sc A2; A3)	Post-Dam recommendation D Scenarios*
Physico chemical	C	C	B/C	B/C
Fish	B/C	B	B	B
Macroinvertebrates	B/C	B/C	B/C	B/C
Riparian vegetation	B/C	B	B	B
EcoStatus	B/C	B	B	B

* Further investigations are necessary on dam sizes to finalise the post-dam scenario recommendations. However, as the differences between the D and C Scenarios are relatively small, an indication of EcoSpecs and TPCs associated with the D scenarios (small dam) has been provided. This will be updated during the Classification study that will folllow.

ORANGE ESTUARY ECOSPECS

The PERC for the components for which EcoSpecs are set as well as the actions required to achieve the PERC are provided below.

Components	PES	PERC	Actions
Hydrology	D	D	Decrease baseflows in winter under current configuration*. (see Section 1.2)
Hydrodynamics	C	C	Increase retention time in winter (this could possibly also facilitate mouth closure under turbulent sea conditions).
Water quality	D	C	Reduce nutrient input in lower Orange River.
Physical habitat alteration	B	B	No improvement required.
Microalgae	E	D	Decrease nutrient input and reduce base flows in winter where possible under current configuration.
Macrophytes	D	C	Reduce nutrient input, remove causeway, control grazing and alien vegetation, reduce soil salinities.
Invertebrates	D	C	Reduce baseflows in winter under current configuration.
Fish	D	C	Reduce baseflows in winter under current configuration, control fishing.
Birds	E	D	Reduce baseflows in winter under current configuration.
EcoStatus	D	C/D	Reduce flows under current configuration, allow for sporadic mouth closure under turbulent sea conditions, and improve vegetation cover and food sources (invertebrates and fish).

* While Sc A2 and A3 does not show substantial benefits for the estuarine ecology indications are that further refinements can possibly facilitate low enough flows under the present configuration to allow for mouth closure under turbulent sea conditions.

WEST COAST ESTUARY ECOSPECS

The PERC for the EcoStatus are provided below. As these estuaries were investigated at a broad level (desktop to rapid), mostly qualitative EcoSpecs are provided per component.

Estuary	PES	REC	PERC	Recommendation to maintain/achieve the PERC
Buffels	D	D	D	The system is on a negative trajectory of change and therefore requires the following interventions to maintain the PERC: ▪ Remove roads/causeways dividing the estuary in three isolated sections (i.e. remnant of mining road at mouth; road at bird hide; road above the golf course). ▪ Improve connectivity with catchment by increasing/establishing culverts in roads in catchments. ▪ Remove invasive alien plants (rooikrans) in upper reaches (in progress).

Estuary	PES	REC	PERC	Recommendation to maintain/achieve the PERC
				▪ Enforce the no driving on the beach legislation to allow for natural sediment processes to re-establish themselves and protect birds (in progress). ▪ Investigate mitigations to reduce nutrient enrichment from golf course irrigation.
Swartlintjies	B	B	B	Maintain PES.
Spoeg	A/B	A/B	A/B	Maintain PES.
Groen	B	A/B	A/B	Components that require interventions or protection to achieve the PERC: ▪ Hydrology: Maintain groundwater flow to near natural levels. ▪ Hydrology: The estuary has a strong dependency on groundwater fed springs to maintain salinity gradient, maintain water levels, limit occurrence of extreme hyper salinity (<150 PSU). ▪ Water Quality: Improve water quality: Investigate possible organic/nutrient seepage from ablution facilities of offices/homes at SANParks and means to address these. ▪ Sediment processes and Macrophytes: Future pressures include an escalation of mining activities in the national park and related disruption of subsurface flow.
Sout	E	D	D/E→D	Components that require interventions to achieve the PERC (and ultimately the REC): ▪ Flow, hydrodynamics, sediment processes and macrophytes: Develop an Estuary Management Plan to evaluate to what extent the current design and/or operations of the salt works can be improved to restore estuarine habitat and functionality of the upper reaches. In progress: Western Cape Government has prioritised this. ▪ Hydrodynamics: Improve circulation (e.g. culverts in roads). ▪ Flow: Restore connectivity with catchment, i.e. investigate if weir can be partially removed to allow connectivity with western arm of estuary.

MONITORING RECOMMENDATIONS

River monitoring with the emphasis on the biological aspects falls into the DWS monitoring programme, the River Ecosystem Monitoring Programme (REMP) (DWS, 2016a). The driver monitoring (hydrology and water quality) is also part of standard DWS monitoring programmes.

With regards to the estuaries, the emphasis is on the abiotic components being monitored by the DWS Estuary Monitoring Programme. Biotic components such as vegetation and birds should also be included. Fish are being monitored by the Department of Agriculture, Forestry and Fisheries at present. The following detail baseline monitoring activities are recommended:

Salinity - Brine shrimp - Bird Dynamics Monitoring Programme: The Small West Coast estuaries play an important role as bird refuge areas. A critical food source for birds in this region is brine shrimp, which in turn is related to the occurrence of low and high salinities in the small systems, i.e. less than <50 PSU likely to be in very low numbers, >150 PSU likely to be in cyst form. A dedicated study needs to be undertaken that focusses on bird abundance and brine shrimp abundance coupled with in situ salinity observations in these small systems.

The role of ground water in maintaining the salinity gradient of the Buffels, Spoeg and especially the Groen Estuaries: Ground water plays an important role in maintaining the springs that flow into the middle and upper reaches of the Groen Estuary (situated in the Namaqualand

National Park). The springs, in turn, moderate the hyper salinity cycles that naturally occur in this system. The location of the springs needs to be mapped and their groundwater requirements established.

Orange Estuary Nutrient Assessment Programme: In the lower Orange River, a comparison between 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.

Orange Estuary Toxin Verification Programme: 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).

Orange Estuary evaluation of the impact of sustained low flows on water column (in-stream) habitat and fish: Detailed Topographical/Bathymetry surveys of the Orange Estuary at low flows are required to determine at what flow ranges the habitat become unsuitable for fish. The geomorphic survey should be conducted at the same time as biological surveys on fish, invertebrates and birds.

Nearshore Orange Marine Environment Ecological Water Requirements: The flow requirements of the nearshore Orange Marine Environment - declared an South African Ecologically or Biologically Significant Marine Areas (EBSA) under the Conversion on Biodiversity Conservation - need to be assed to quantify the impact of the proposed Vioolsdrift dam development on the provision of sediments, organics, nutrients and freshwater fronts to the beaches and nearshore marine environment. This aspect needs to be formally addressed as part of the Classification.

GROUNDWATER MONITORING

Several areas have been identified as being stressed in terms of high stress indices, declining water levels, and sole source dependency. By examining trace groundwater quality constituents in the Department of Water Affairs and Sanition ZQM database, severeal chemical parameters which sometimes exceed potable standards were identified, these being Arsenic and Molybdendum. Most of the priority stressed catchments are located in the south, the Karoo sandstone and shale GRUs, which are the target area for potential fracking.

Sole source aquifers are highly dependent on groundwater, and where they have a high stress index, monitoring of abstraction and water levels is necessary. Contamination or large abstractions from fracking or other activities could cause significant deterioration in water supply to such communities.

The identified high priority stressed catchments include:

- D53C in the vicinity of Kenhardt.
- D57A due to irrigation registration, whose actual use needs to be verified.
- D57C in the vicinity of Brandvlei and where no data is currently available.
- D54B in the vicinity of Carnarvon where insufficient data is available. Monitoring for arsenic is also recommended.
- D55L in the vicinity of Williston due to irrigation registration yet water level data is inadequate and sparse.
- D82K in the vicinity of Kuboes where no data is currently available. Monitoring for arsenic is also recommended.
- F20D in the vicinity of Port Nolloth where insufficient data is available. Monitoring for arsenic is also recommended.
- The dolomites of the Ghaap plateau where water data is available only in the vicinity of Griekwastad. Monitoring for arsenic is also recommended.
- D55D in the vicinity of Loxton where water level declines are evident. Monitoring for arsenic and molybdenum is also recommended.
- D55E in the vicinity of Fraserburg where water level declines are evident. Monitoring for arsenic and molybdenum is also recommended.
- D61A in the vicinity of Richmond where water level declines are evident. Monitoring for arsenic and molybdenum is also recommended.
- D61E in the vicinity of Victoria West Loxton where insufficient data is available. Monitoring for arsenic and molybdenum is also recommended.
- D62C and D where a suitable network exists but monitoring has declined since 2005. Monitoring for arsenic and molybdenum is also recommended.
- F30D in the vicinity of Springbok where water level is available only since 2014, which is of too short a duration. Monitoring for arsenic is also recommended.
- D51A in the vicinity of Sutherland where significant water level declines are evident since 2014.

IMPLEMENTATION

Recommendations are to immediately implement the Preliminary Reserve which requires as a first option the adjustment of the operating rules in terms of the existing environmental allocation released from the Orange River Project (Gariep and Vanderkloof Dams). The major difference in operation will be that the new Preliminary Reserve release will be variable and will be dependent on the upstream catchment conditions in terms of preceding rainfall. A methodology will need to be developed whereby observed rainfall at selected points in the upstream catchment is converted into anticipated streamflow under natural conditions. The required EWR will then be determined based on the natural streamflow, and the required releases will then be calculated in order to allow the water to reach the EWR site. A model will need to be configured to assist with implementation, taking into consideration observed flows (especially from the Vaal) and actual abstractions along the river.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

ASPT	Average Score Per Taxon
BHN	Basic Human Needs
CD: WE	Chief Directorate: Water Ecosystems
CEV	Chronic Effects Value
CPUE	Catch per Unit Effort
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphate
DO	Dissolved oxygen
DWA	Department of Water Affairs
DWAF	Department of Water and Forestry
DWS	Department of Water and Sanitation
EBSA	Ecologically or Biologically Significant Marine Areas
EC	Ecological Category
EcoSpecs	Ecological Specifications
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
FIFHA	Fish and Invertebrate Flow Habitat Assessment
FRAI	Fish Response Assessment Index
FROC	Frequency Of Occurrence
GRU	Groundwater Resource Unit
HF	Hydraulic fracturing
HPLC	High-performance liquid chromatography
ind/min	Individual per minute
JBS	Joint Basin Survey
MCB	Macro Channel Bank
MIRAI	Macroinvertebrate Response Assessment Index
MPB	Microphytobenthos
MRU	Management Resource Unit.
NEMP	National Estuarine Management Protocol
NGO	Non-governmental organisation
NWRS	National Water Resource Strategy
ORASECOM	Orange-Senqu River Commission
ORP	Orange River Project
ORRS	Orange River Replanning Study
PERC	Preliminary Ecological Reserve Category
PES	Present Ecological State
PSD	Particle Size Distribution
PSP	Professional Service Provider
PTV	Pollution Tolerant diatom Valves
REC	Recommended Ecological Category
REMP	River Ecosystem Monitoring Programme
RQO	Resource Quality Objective
SASS	South African Scoring System
Sc	Scenario
SPI	Specific Pollution Index
SRP	Soluble Reactive Phosphorous
TDI	Trophic Diatom Index

TEACHA	Tool for Ecological Aquatic Chemical Habitat Assessment
TIN	Total Inorganic Nitrogen
TOR	Terms of Reference
TPC	Threshold of Potential Concern
TWQR	Target Water Quality Range
WMA	Water Management Area
WMS	Water Management System
WRC	Water Research Commission

Velocity Depth Classes: Fish and Macroinvertebrates

FD	Fast Deep fish habitat
FS	Fast Shallow fish habitat
SD	Slow Deep fish habitat
SS	Slow Shallow fish habitat

1 INTRODUCTION

1.1 BACKGROUND

The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) initiated a study for the provision of professional services to undertake the 'Determination of Ecological Water Requirements for Surface Water (Rivers, Estuaries, and Wetlands) and Groundwater in the Lower Orange Water Management Area (WMA). The appointed Professional Service Provider (PSP) to undertake this study was Rivers for Africa.

As per the Terms of Reference (TOR), there is a need to undertake detailed Ecological Water Requirement (EWR) and Basic Human Needs (BHN) studies for various water resource components due to mainly:

- Planned hydraulic fracturing (HF) undertaken in the WMA.
- Various water use licence applications.
- The conservation status of various Resources in this catchment; and
- The associated impacts of proposed developments will have on the availability of water.

1.2 STUDY AREA

As indicated in the TOR, the study area is the Lower Orange River WMA (the old WMA 14). It is the largest WMA in the country and covers almost the entire Northern Cape Province. This core area forms part of the Orange-Senqu River Basin, which straddles four International Basin States with the Senqu River originating in the highlands of Lesotho, Botswana in the north-eastern part of the Basin, the Fish River in Namibia and the largest area situated in South Africa. The focus area of the study comprises only the South African portion of the Lower Orange River Catchment. The Eastern Boundary starts where the Vaal River Tributary enters the Orange River, and the Western Boundary is the Atlantic Ocean. The study area is downstream of the Upper Orange, Senqu, and the Integrated Vaal River System and as such, affected by the upstream activities in the highly developed river basin. The Orange River forms the border between the Republic of South Africa (RSA) and Namibia to the west of the 20 degrees longitude over a distance of approximately 550 km.

1.3 LOCALITY AND DESCRIPTION OF EWR SITES

The locality of the EWR sites within the Management Resource Units (MRUs) as identified during this study is provided in Table 1.1 and their locality are illustrated in Figure 1.1.

Table 1.1 Locality and characteristics of EWR sites

EWR site number	EWR site name	River	Latitude	Longitude	EcoRegion (Level II)	Geozone	Altitude (m)	MRU	Quat	Gauge
EWR O2	Boegoeberg	Orange	-29.0055	22.16225	26.05	Lowland	871	MRU Orange D, RAU D.1	D73C	D7H008
EWR O3	Augrabies	Orange	-28.4287	19.9983	28.01	Lowland	433	MRU Orange E	D81B	D7H014
EWR O4	Vioolsdrift	Orange	-28.7553	17.71696	28.01	Lowland	167	MRU Orange F	D82F	D8H003 D8H013
EWR O5	Sendelingsdrift	Orange	-28.0718	16.95951		Lowland	47	MRU Orange G	D82L	D8H015

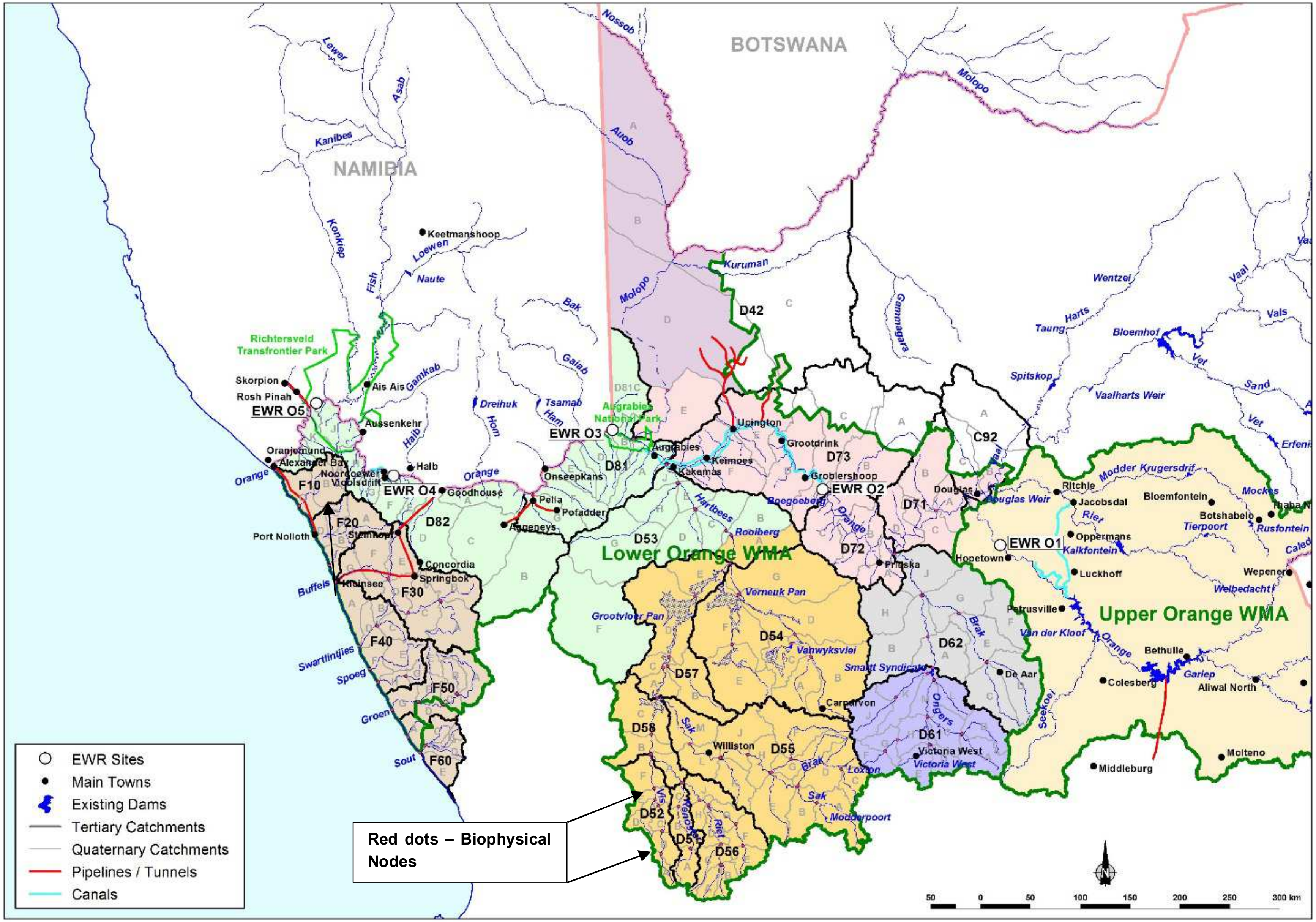

Figure 1.1 Location of EWR sites in the Lower Orange River

1.4 PURPOSE OF THIS TASK

The purpose of this task is to update the 2013 monitoring plan (Louw *et al*., 2013a) according to the principles of adaptive management. The broad objectives of monitoring are to:

- Set Ecological Specifications (EcoSpecs) and Thresholds of Potential Concern (TPCs) for the Orange River and Estuary. This has been undertaken for the lowest EWR site (EWR O5) and the estuary and will be revised if necessary. The same methods and approaches were used to provide EcoSpecs at EWR O1, 2, 3 and 4, as well as for the five additional estuaries taking recent biomonitoring activities and results into consideration.
- Update the existing Orange Estuary monitoring programme with the findings of this study.
- Provide a river monitoring programme: The monitoring programme was designed for the EWR sites (in terms of hydrology and water quality) and the estuary. The estuary and EWR O5 has been included in a detailed monitoring programme as part of the 2013 EWR study and was updated to include the five additional estuaries. Monitoring the implementation and execution of the related system operating rules was included in the monitoring programme. No further information was supplied for the river monitoring programme in terms of habitat and biota as this is addressed through the River Ecosystem Monitoring Programme (REMP) (DWS, 2016a) and must be undertaken according to DWS procedures.
- Compilation of a monitoring programme for groundwater resources: Future monitoring requirements for groundwater were identified while undertaking the project. Key Indicators of where additional monitoring is needed but not already available included:
  - Stressed catchments where groundwater use is a significant proportion of recharge, or where future use due to fracking and associated infrastructure, requires water use and water level monitoring.
  - Catchments where baseflow exists and is significant to the EWR but gauging data and water level data is not available.
  - Good groundwater quality areas where hydraulic fracturing may occur.
  - Wetlands and estuaries where groundwater inflows are suspected to exist but water level data is not available.

1.5 ECOSPECS IN CONTEXT OF THE PRELIMINARY ECOLOGICAL RESERVE CATEGORY

EcoSpecs relate to the ecological objectives in terms of the Ecological Category (EC) associated with the Preliminary Reserve. It follows therefore that prior to determining EcoSpecs, a decision is required regarding the scenarios to be selected and the Preliminary Reserve and associated EC.

The purpose of setting Preliminary Reserves are to provide the management guidance for the system that is legally binding. The Preliminary Reserve will be superseded once Classification has been undertaken and gazetted, followed by the gazetting of the Reserve based on the Classification decisions. Considering this, and based on the assumption that the future dam development will not be in place prior to Classification taking place, the Preliminary Reserve that is recommended is based on the pre-development (dam) situation. The EC linked to the recommended pre-development scenario is referred to as the Preliminary Ecological Reserve Category (PERC). As the Recommended Ecological Category (REC) cannot always be met, the PERC represents the realistic EC that will be signed off. The PERC may be the REC, or any other category that is attainable.

The PERC is summarised in Table 1.2 below. Details on the PERC recommendations will be available in the Main Report (RDM/WMA06/00/CON/COMP/0317).

Table 1.2 PERC for the EWR sites and Estuary

EWR Site	PES	REC	PERC	Comment
O3	C	B	B/C	With current constraints, improvement is only possible to a B/C.
O4	C	B/C	B/C	Although the EcoStatus is met, all component RECs are not met.
O5	B/C	B	B	REC is fully met
Estuary	D	C	C/D	C/D can only be achieved with non-flow related mitigation. Without a dam, flow to achieve the additional improvement to get to a C is not available.

There are specific links between the Preliminary Reserve, Classification, Reserve and Resource Quality Objectives. An explanatory text block is provided below.

INTRODUCTION: PRELIMINARY RESERVE, CLASSIFICATION, RESERVE

- Determination of the Reserve and the National Water Resources Classification is a legal requirement according to the National Water Act.
- The Reserve can only be gazetted once the Classification has been determined and gazetted.
- The act allows for a Preliminary Reserve to be determined prior to Classification. Although not gazetted, the Preliminary Reserve is signed off by the Minister (or the delegated authority) and is legally binding.
- As such, the Preliminary Reserve is undertaken prior to Classification or as part of a Classification study.
- The decisions taken can be reviewed and updated during Classification as detailed consideration is given to the socio-economic issues.
- The Orange River study is determining the Preliminary Reserve prior to Classification.
- Further development of the Orange River is on the table and will happen. This will allow for more management options of amongst others, the EWRs.
- The scenarios and recommendations which are made for this phase pertain to the ***post-dam recommendations***.
- Immediately applicable is the provision of EWRs through the operation of the system without additional storage.
- These are referred to as the ***pre-dam scenarios*** and will be immediately applicable.
- **Therefore, the focus of this (Preliminary) Reserve study is on pre-dam situation.**
- Recommendations are also made for the post-dam situation regarding scenarios as well as further work required in preparation for Classification.

Difference between the Preliminary Reserve and Classification:
The Preliminary Reserve focusses on ecological objectives and BHN.
Classification considers the balance between protection and use.

1.6 ECOSPECS, TPCs AND MONITORING

EcoSpecs are biological specifications that are numerical values or narrative statements that define a desired biological condition (EC). They indicate the level of habitat integrity that is required to attain a specific biological condition for the river and therefore provides the ecological detail that characterises the EC. For a Preliminary Reserve, it would be the biological conditions relating to the PERC.

EcoSpecs must be quantifiable, measurable, verifiable and enforceable and ensure protection of all components. TPCs indicate the numerical values around the EcoSpecs that, if approached, would initiate more detailed investigations or even management actions. TPCs are therefore upper and lower levels along a continuum of change in selected environmental indicators (Rogers and Bestbier, 1997) and represent early warning indicators of potential change from a particular EC to another EC (warning bell).

Ecological monitoring is the collection and analysis of repeated observations or measurements to evaluate change in the condition of the resource and the progress towards meeting the management objective (Elzinga *et al.,* 1998). As used with DWS, it is the measurement of EcoSpecs to determine if the PERC is attained (Kleynhans *et al.,* 2009). The Present Ecological State (PES) acts as the baseline against which change is monitored. Management objectives are set for the drivers (e.g. hydrology) to achieve the PERC. Monitoring of drivers is part of compliance monitoring – standard activities of DWS. Monitoring the ecological responses focus on determining whether the PERC is reached and if not, what the problems are. Ecological monitoring will therefore identify problems and within a monitoring programme, indicate the next actions required. Compliance monitoring is used to determine the management actions that may be required to rectify the problems

During the Reserve step, EcoSpecs are determined. Ecological Specifications are the numerical Resource Quality Objectives (RQOs) for habitat and biota. This also includes water quality in the ecological context which will form part of the habitat EcoSpecs. Furthermore, the flow EcoSpecs is represented by the Preliminary Reserve for the PERC.

Once the Preliminary Reserve has been signed off, measures must be put into place to measure and ensure that the goals (in terms of the preliminary Ecological Reserve Category) are being met. Firstly, Ecological Specification for the relevant EC is defined. The purpose of determining EcoSpecs is therefore to define measurable goals against which to monitor whether the objectives (in terms of ECs) are being met.

Secondly, a monitoring programme must be put in place to ensure that the necessary implementation of the Preliminary Reserve is put in place, and that a programme of actions, linkages and responses are available to address the results of monitoring. This monitoring will be both in terms of measuring the physical drivers (e.g. flow and water quality) as well as whether the biological responses are meeting the targets.

DWS currently has a REMP and the Reserve monitoring must be undertaken under the auspices of this programme.

With regards to estuaries, the process is somewhat different as there is more than one responsible authority involved. Estuarine monitoring is currently not a routine activity of national departments. Where routine estuarine monitoring activities do occur, it is undertaken by fisheries research (Department of Agriculture, Forestry and Fisheries on large temperate systems), conservation authorities, provincial authorities or local authorities, and only includes a limited selection of variables. More recently the DWS (Resource Quality Information Services) commenced with the role out of a national estuarine water quality monitoring programme. Currently, implementation of water quality compliance monitoring activities in the Orange Estuary is dependent on collaboration with other responsible authorities or non-governmental organisation (NGOs). It is strongly recommended that the estuarine management planning process (a requirement under the Integrated Coastal Management Act), be used as a vehicle to coordinate the implementation of these compliance monitoring activities.

South Africa's estuaries have a diversity of management requirements, often unique to individual systems, and are governed by a variety of authorities, from national to local level. Consequently, it was necessary to develop a flexible, but legally defensible National Estuarine Management Protocol (NEMP) providing guidance to estuarine managers at all levels to develop sound management plans to suit individual systems. In the case of estuaries, protection is not only effected by localised management actions but also through ensuring adequate quantity and quality of freshwater flows into the estuary. The outcome of a Reserve Study therefore informs and supports other estuary planning initiatives, and products developed as part of this process are aligned as much as possible with other management initiatives. In turn, the interventions required to achieve a specific ecological state, and the monitoring actions required to measure if such targets are achieved, will be taken up in individual Estuary Management Plans. Monitoring is incorporated in the Estuary Management Plans.

There is a specific relationship between EcoSpecs and Resource Quality Objectives and an explanatory text box is provided below:

ECOSPECS AND RESOURCE QUALITY OBJECTIVES (RQOs)

- RQOs are numerical and/or descriptive statements about the biological, chemical and physical attributes that characterise a resource for the level of protection defined by its Class. The **National Water Resource Strategy** (NWRS) therefore stipulates that "Resource Quality Objectives might describe, among other things, the quantity, pattern and timing of instream flow; water quality; the character and condition of riparian habitat, and the characteristics and condition of the aquatic biota".
- RQOs are determined and gazetted after Classification has been gazetted.
- RQOs include EcoSpecs as well as other non-ecological aspects.
- For a Preliminary Reserve Study, the focus is only on the ecological endpoint in terms of EcoSpecs.
- EcoSpecs therefore capture the PERC into measurable management goals that give direction to resource managers.

1.7 OUTLINE OF THIS REPORT

The report outline is provided below.

Chapter 1: Introduction
This Chapter provides a general background to the project, study area and purpose of the report.

Chapter 2: Approach and Methods: Rivers
An outline of the approach and methods followed during the determination of EcoSpecs and TPCs for rivers, and estuaries are provided.

Chapter 3: Approach and Methods: Small West Coast Estuaries
This section provides an outline of the approach followed to determining the EcoSpecs of the small estuaries in the Lower Orange for the PERC.

Chapter 4: Approach and Methods: Orange Estuary
This section provides an outline of the approach followed to determining the EcoSpecs and TPC of the Orange Estuary.

Chapter 5 - 7: River EcoSpecs and TPCs
Detailed EcoSpecs and TPCs for EWR O3 – O5 are provided.

Chapter 8: Estuaries: EcoSpecs and TPCs
Detailed EcoSpecs and TPCs are provided for the Orange Estuary and the small West Coast estuaries assessed during the Study.

Chapter 9: Estuaries: Monitoring Recommendations
This section summarises the remedial actions required to improve the condition of the Orange Estuary and the small West Coast estuaries as well the monitoring requirements to improve confidence in future studies.

Chapter 10: Groundwater Monitoring
A suggested monitoring programme for groundwater resources is provided.

Chapter 11: Preliminary Reserve Implementation
Recommendations are provided for the implementation and monitoring of the suggested operating rule.

Chapter 12: References

Appendix A: EWR O2 (Boegoeberg): EcoSpecs and TPCs
Although EWR O2 is not a key monitoring site, EcoSpecs and TPCs are provided as documented in Louw and Koekemoer (2010a).

Appendix B: Comments Register
Comments from the Client are provided.

2 APPROACH AND METHODS: RIVERS

The approach and methods from the 2010 EWR study (Louw and Koekemoer, 2010a) were adopted and have been updated and revised where necessary.

2.1 WATER QUALITY

Authored by P-A Scherman

The water quality assessment for the Orange River sites EWR O3 and O4 was undertaken during the 2010 study (Louw and Koekemoer, 2010b) and the 2013 study (Louw *et al.*, 2013b) for EWR O5. These assessments included the use of biotic response data, i.e. diatoms and chlorophyll-a (periphyton and phytoplankton), as well as the suite of physico-chemical data normally used for such an assessment. This document also assumes that the monitoring baseline has been set for the sites and that all evaluations are therefore relative to knowledge of the natural state of the catchment.

The approach followed for each site was therefore as follows:

- EcoSpecs, i.e. water quality specifications or objectives for the PES and selected scenarios, were set for physico-chemical parameters and response indicators. Although macroinvertebrate and fish data were evaluated in the water quality assessment, they were not used to set categories but rather to assess the accuracy of the water quality category.
- Quality EcoSpecs are therefore related to attaining the recommended water quality category of the selected scenarios, and are presented as the range that each variable should be in to maintain the required category for that variable.
- Data for defining EcoSpecs and TPCs are presented as 95th percentiles, i.e. values not to be exceeded more than 5% of the time, for inorganic salts, physical variables and toxics; and 50th percentiles for nutrients, i.e. Total Inorganic Nitrogen (TIN), Soluble Reactive Phosphorous (SRP) or ortho-phosphate and chlorophyll-a (chl-a). The TPC ranges are defined by the upper boundary of the PES category and 80% thereof for the lower boundary, e.g. if a B Category for a PES EcoSpec is <15 mg/L, the associated TPC would be 12 - 15 mg/L.
- It is recommended that monitoring for salts rely on the EcoSpec and TPC for Electrical Conductivity. Although EcoSpecs and TPCs were also provided for integrated salts where possible in previous studies, the programme used to produce integrated salts, Tool for Ecological Aquatic Chemical Habitat Assessment (TEACHA), is no longer available or in use. However, TEACHA was only recommended for use when the TPC for Electrical Conductivity was exceeded.
- Use of diatom data: Diatom data received from the diatomologist for the study, Ms Shael Koekemoer included the diatom EC based on the Specific Pollution sensitivity Index (SPI) score, water quality conditions indicated by her results and detailed information regarding the diatom community structure and water quality state it indicates.

It should be noted that diatom data provides useful information on pollution events. Data should be interpreted together with long-term water quality data, which incorporates deviation from natural. Note that due to the paucity of diatom data, reference condition data are not normally available.

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

Management System's (WMS) database. Toxics data used for the assessment should be used to develop a database of information for these variables, as they are generally not monitored by DWS.

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

2.2 DIATOMS

Authored by S Koekemoer

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

Important note:

Currently there are no methods developed specifically for deriving EcoSpecs and TPCs for diatoms, although some developmental work has been produced over the past five years. Therefore it is very important to note that the approach and method provided in this document has not been tested and should be viewed as experimental. The methods outlined below are based on the Diatom Assessment Protocol, a Water Research Commission (WRC) initiative in South Africa, and should be used by a diatomologist with experience in detailed diatom analysis as outlined in Taylor *et al*. (2007a;b).

OMNIDIA (Lecointe *et al*., 1993) Software was used for the determination of EcoSpecs and TPCs as well as generating diatom index scores at the EWR sites. This software was developed for the purpose of including and calculating diatom indices in studies relating to water quality. It is the most widely used and preferred data base in South Africa and was used during all relevant studies.

2.2.1 Approach

Within the context of this study, diatoms should be used as a **water quality screening tool** to indicate if:

- A particular physico-chemical metric needs further monitoring to assess the cause of the extent of the change.
- Management action is needed.
- For diatoms to function as an effective water quality screening tool the results generated should:
    - Provide information on diatoms as an additional response variable to compliment the physico-chemical driver component of the monitoring programme.
    - Provide additional information and interpretive results, especially at sites where 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 SPI (Coste in CEMAGREF, 1982).

General diatom monitoring guidelines were developed for the different EWR sites based on the diatom community composition and the associated temporal and spatial changes exhibited by the community under different flow conditions. Key indicator species/genera that most frequently indicate problems relating to physico-chemical metrics under South African conditions and applicable to the specific EWR sites was identified with the focus being on the general measure of system recovery of the river reach as well as indicating notable changes in selected metrics.

The physico-chemical metrics and variables of importance for diatoms included in the approach are listed below and considered the most important and frequent pollution related impacts encountered in South African rivers that is discussed in detail in Dallas and Day (2004):

- pH.
- Salinity.
- Nutrients.
- Oxygen.
- Organics.

Most of the indices included in OMNIDIA were designed to evaluate at least one of these metrics. Note that there is adequate information available on the relationship between these metrics and diatom based water quality indices as well as the tolerance limits of diatom species for the different metrics. The selected metrics also provide the necessary information for additional input to the physico-chemical driver component within the monitoring programme (Dr Scherman, *Pers. Comm.*, January 2015).

General guidelines are provided per site which provides information on specific species which would influence the overall SPI score as well as pollution related events which would lead to an increase in these species. Although there are many species that could lead to a change in community composition and ultimately altered SPI scores, the species included in the guidelines are species that occurred frequently in the samples during 2005, 2008 – 2010, 2013 and 2015, and are specifically good indicators of deteriorated water quality conditions or changes in community composition due to water quality changes at the specific EWR site. The results from the Trophic Diatom Index (TDI) (Kelly and Whitton, 1995) were also taken into account as this index provides the percentage pollution tolerant diatom valves (PTVs) in a sample and was developed for monitoring sewage outfall (orthophosphate-phosphorus concentrations), and not general stream quality. The presence of more than 20% PTVs shows significant organic impact.

2.2.2 Metal toxicity

The presence of valve[1] deformities is an indication of possible metal toxicity that may be present within the aquatic system. According to Luís *et al*. (2008) several studies on metal polluted rivers have shown that diatoms respond to perturbations not only at the community but also at the individual level with alteration in cell wall morphology. In particular, size reduction and frustule deformations have been sometimes associated with high metal concentrations. The general threshold for valve deformities is usually considered potentially hazardous if the valve deformities make up between 1 - 2% of the total count.

2.2.3 Available data

Various sets of data were available for this study and included:

[1] Siliceous part of the diatom cell wall, containing most of the morphological features used to describe diatoms.

- Samples collected during 2005 as part of Orange River study on assistant pollutants on sediment. Samples were taken from Douglas to the Orange River Mouth.
- Samples collected during April - June 2008 and during August - September 2009 as part of a water quality monitoring and status quo assessment study of the Orange-Senqu River and associated tributaries (DWA, 2009).
- Samples taken at the site as part of the ORASECOM Joint Basin Survey 1 (JBS 1) – Water Resources Quality Monitoring, undertaken during 2010 (ORASECOM, 2011a;b).
- Samples collected at the EWR sites as part of 2010 study (Louw and Koekemoer, 2010a; Koekemoer, 2010).
- Samples collected at the EWR sites as part of 2013 study (Louw *et al*., 2013b;c).
- Samples taken at the site as part of the ORASECOM Joint Basin Survey 2 (JBS 2) – Water Resources Quality Monitoring, undertaken during 2015 (ORASECOM, 2015).

Data sets applicable to the various EWR sites have been summarised and is provided electronically.

2.3 RIPARIAN VEGETATION

Authored by J Mackenzie

2.3.1 Method

The following vegetation components, when assessed together and compared to reference conditions, satisfactorily describe the overall state of any riparian site: exotic invasion, terrestrialisation, general vegetation structure as shown by proportions of riparian woody species, reeds and non-woody species (grasses, sedges and dicotyledonous forbs). Note that EcoSpecs (and hence TPCs) are based on hypotheses and these need to be refined, most likely through a decision support system. All components are estimated aerial cover (%) as this facilitates ease and speed of assessments.

2.3.2 Exotic invasion

Ecological specifications were set for the proportion of exotic species invading the riparian zone (Table 2.1). Values were tested by assessing a number of existing sites where exotic aerial cover data were available. Values of perennial exotic species aerial cover (%) in Table 2.1 were used to assess all sites on the Orange River since the reference percentage cover of exotics is not expected to change for different sites or different systems, and is therefore robust enough to transfer across sites.

Table 2.1 Hypothesis on which EcoSpecs for exotic perennial species occurrence in the riparian zone is based

Ecological Category	% Aerial Cover (Perennial Exotics)
A	0
A/B	1 - 5
B	5 - 10
B/C	10 - 15
C	15 - 20
C/D	20 - 30
D	30 - 50

Ecological Category	% Aerial Cover (Perennial Exotics)
D/E	50 - 60
E	60 - 70
E/F	70 - 80
F	>80

2.3.3 Terrestrialisation

The occurrence of terrestrial species in the riparian zone is based on the phenomenon that terrestrial species occur naturally in the riparian zone (to greater or lesser degrees depending on vegetation biomes), but are reduced in cover and abundance by increased flooding disturbance. As the focus is on woody terrestrial species and the sites occur in Nama-karoo, or Desert biomes, expected cover is low since the upland species pool able to contribute is sparse, succulent, grass or scrub. Table 2.2 outlines a hypothesis for EcoSpecs for the occurrence of terrestrial woody species in the riparian zone.

Table 2.2 Hypothesis for EcoSpecs concerning terrestrialisation of the riparian zone

Ecological Category	Marginal Zone	Lower Zone	Upper Zone
A	0	0	0 - 5
A/B	0	0	5 - 10
B	0	0	10 - 15
B/C	0	1 - 5	15 - 20
C	0	5 - 10	20 - 30
C/D	0	10 - 15	30 - 40
D	1 - 5	15 - 20	40 - 50
D/E	5 - 10	20 - 30	50 - 60
E	10 - 15	30 - 40	60 - 70
E/F	15 - 20	40 – 50	70 - 80
F	>20	>50	>80

2.3.4 Indigenous riparian woody cover

The proportion of woody riparian species in the riparian zone is not as easily transferrable to different sites and rivers as is exotic and terrestrial vegetation. The sites that have been selected in the Orange catchment fall into different biomes: Nama-Karoo (EWR O2 and O3), Desert (EWR O4), and some occur close to the Ecozone between Savannah and Nama-Karoo (EWR O1). Sites EWR O1 - O4, however, occur in azonal vegetation units (Lower and Upper Gariep Alluvial Vegetation), which can be treated similarly in terms of expected proportions of riparian woody cover. The hypothesis for sites in Lower and Upper Gariep Alluvial vegetation is based on the occurrence of riparian woody dominant species characteristic of these vegetation units, and on a dynamic whereby riparian vegetation will always tend towards increased woody cover with diminishing non-woody cover (including reeds), this being "reset" by large flood events. "Reset" here refers to the removal of woody plants by floods, with the resulting open space being available for quick colonising by non-woody species (including reeds). The hypothesis assumes that if woody cover increases beyond a given value and remains high, that the flooding regime has been changed so that large floods are smaller or less frequent. Because flooding frequency and disturbance decreases up the bank, the expected cover of riparian woody species will increase. Tables 2.3 and 2.4 outlines a basic expected pattern of riparian woody cover, but is general in nature and has been changed slightly where necessary to more realistically reflect site characteristics when setting EcoSpecs and TPCs for each site (see EcoSpec and TPC detail below).

Table 2.3 General hypothesis for EcoSpecs concerning indigenous riparian woody cover (% aerial cover) for sites in Upper or Lower Gariep Alluvial Vegetation

Ecological Category	Marginal Zone		Lower Zone		Upper Zone		MCB*	
A	10 - 30		10 - 20		30 - 50		70 - 80	
A/B		30 - 40		20 - 40	20 - 30	50 - 60	60 - 70	80 - 90
B	5 - 10	40 - 60	5-10	40 - 50	10 - 20	60 - 70	40 - 60	>90
B/C		60 - 70				70 - 80	20 - 40	
C	1 - 5	70 - 80	<5	50 - 60	5 - 10	80 - 90	10 - 20	
C/D							<10	
D	0	>80		60 - 70	<5	>90		
D/E								
E				70 - 80				
E/F								
F				>80				

* Macro Channel Bank

Table 2.4 Hypotheses for EcoSpecs concerning indigenous riparian woody cover (% aerial cover) for sites in the Grassland Biome (such as EWR C5)

Ecological Category	Marginal Zone		Lower Zone		Upper Zone		MCB	
A	10 - 20		10 - 20		<5		0	
A/B	5 - 10		5 - 10					
B		20 - 30		20 - 30		5 - 10		1 - 10
B/C	1 - 5		1 - 5					
C	0	30 - 40	0	30 - 40		10 - 25		10 - 20
C/D								
D		>40		>40		25 - 60		20 - 50
D/E								
E						>60		>50
E/F								
F								

2.3.5 *Phragmites* (Reeds) cover

For sites occurring in Lower or Upper Gariep Alluvial Vegetation (EWR O1 to O4), this hypothesis is based on the expectation that reeds should always be components of marginal and lower zone vegetation (Table 2.5), that their unchecked increase in aerial cover is a change away from reference, and that their occurrence in the upper zone should be low. The hypothesis assumes that reeds will colonise open alluvium (similar to the pioneer species concept) created by floods, and will increase in cover until slowly replaced by woody vegetation as shading occurs. A natural flow regime will create a patch mosaic of woody vs. reeded areas, thus a mix is always expected (in the absence of very infrequent extreme events): an increase in reed cover beyond a specified value is seen to be a loss of riverine diversity and as such will begin to reduce the EC.

Table 2.5 Hypotheses for EcoSpecs concerning *Phragmites* (Reed) cover (% aerial cover) for sites in Upper or Lower Gariep Alluvial Vegetation

Ecological Category	Marginal Zone		Lower Zone		Upper Zone	
A	10 - 20		10 - 20		<5	
A/B		20 - 30		20 - 30		
B	<10	30 - 40	<10	30 - 40		5 - 10
B/C						
C		40 - 50		40 - 50		10 - 20
C/D						
D		50 - 60		50 - 60		20 - 30
D/E						
E		60 - 80		60 - 80		30 - 40
E/F						
F		>80		>80		>40

2.4 FISH

Authored by P Kotzé and A Deacon

Detailed EcoSpecs and TPCs for fish can only be done for the PES since it is based on actual observed data (frequency of occurrence, catch per unit effort, presence/absence of indigenous and alien fish species, etc.). The estimated EcoSpecs for any alternative categories (such as the REC, or operational scenarios) was done broadly as a prediction of the estimated Frequency of Occurrence (FROC - Kleynhans and Louw, 2007) under these different ecological categories. No detailed EcoSpecs (catch per unit effort, abundance etc.) can be estimated for alternative categories. It is furthermore important to note that these EcoSpecs need to be verified and adapted during the monitoring phase. It must also be mentioned that other monitoring tools and developments (e.g. REMP, FIFHA[2] model as developed by DWS) should also be tested and considered for inclusion in future monitoring programmes).

EcoSpec and TPC results were provided in an MS Excel format (Fish EcoSpecs and TPCs) for the relevant site, which includes methodology and supporting data and information for future reference, especially during application of TPCs after monitoring. This data is also provided electronically.

The approach for determining EcoSpecs and TPCs and the use of the electronic spreadsheet (Fish EcoSpec and TPC) are described in sheet 1 of the Excel spreadsheet in a step-wise manner. These steps are listed below (Bold typeface), with further explanation provided.

- **<u>Step 1: Populate spreadsheet with relevant data</u>:** Import information from FRAI (Fish Response Assessment Index – Kleynhans, 2007) model (PES and REC) into relevant sheets (sheet 5 to 10) and follow the instructions at the top of each spreadsheet.
- **<u>Step 2: Selection of indicator taxa for different metrics (worksheet 2-EcoSpecs&TPCs)</u>:** Select indicator taxa for each metric (in worksheet 2-EcoSpecs&TPCs, column C) using sheets

[2] Fish and Invertebrate Flow Habitat Assessment Model: Kleynhans and Thirion (2016).

7 to 10 and referring to sheet 5 to determine whether a species was sampled at the relevant EWR site (only use species known to occur at the site for the purpose of site specific EcoSpecs and TPCs). Use one or two of the highest ranked species (present at site) and list them in Column C (2-EcosSpecs&TPCs worksheet).

The selection of indicator taxa for each metric is conducted using the 'monitoring indicator' sheet in the FRAI model for each EWR site/reach. This sheet calculates an indicator value per species for different variables (such as fast shallow habitats, cover type, etc.) based on the reference FROC and relative intolerance rating of the species. Based on the indicator value determined by the model, species are ranked (manually for each metric/variable) in order of importance to serve as indicator for a specific variable. The two highest ranked species that are known to occur at the EWR site were generally used as the indicator taxa for the specific metric. If there was uncertainty about the presence of an optimal indicator species (ranked 1 and 2) at a site, or if the species occurred in too low an abundance and sampling may therefore be coincidental, these species were excluded and replaced by lower ranked indicator taxa at the site. The two highest ranked indicator species for each metric was used as indicators for the reach (automated in the Excel spreadsheet) by default. This should be edited if a species expected under natural conditions is thought not to be present in the reach under present conditions.

- **Step 3: Describing EcoSpecs and setting TPCs in sheet 2-EcoSpecs&TPCs:** Describe PES EcoSpecs and TPCs for each metric per site and reach (columns D,E,F and I), and EcoSpec for the REC (reach only) (column J). This should be done using the spatial and temporal[3] FROC as well as relative abundance information in the worksheet labeled 5-FROC.

Site versus reach EcoSpec assessment

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

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

Spatial and temporal FROC of species, as well as their relative abundance (Catch Per Unit Effort or CPUE), were used as units for the different variables or metrics. The calculation of the FROC and relative abundance is based on the results gained during the baseline (generally EWR)

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

surveys, and sometimes also on other available data (important to note that EcoSpecs and TPCs should reflect the PES). Historic data should be used with care in cases where changes could have occurred since the surveys were conducted. The use of data from other sites in a reach must also be applied with circumspection as it may not reflect the species composition and relative abundances of the specific EWR site. It is imperative to note that the recommended values given as TPCs should be tested and refined over time as more information becomes available. This is however the best available information at present and should serve as an appropriate starting point.

It is acknowledged that use of “abundance” (measured in CPUE) as a metric in the setting of EcoSpecs may require further verification and testing. It is however important (as described in literature) that in a low fish species diversity ecosystem (typical of cold water systems), the use of fish species diversity (presence/absence) alone may not be an adequate measure of change, since the range of species may not adequately represent varying intolerances to a different stressors. It is also a known fact that a change in abundance is often the first indication of a change in ecosystem health and hence a more conservative approach to use as an early warning system (rather than waiting for a species to disappear before reacting). The measure of abundance can be variable and is dependent on especially sampling method and season. It is however stated in the EcoSpecs that monitoring should ideally be applied during similar seasons and using similar sampling methods, and that these values need to be verified and where applicable amended over time.

- **Step 4: Ranking metrics:** Based on metric group weight (Sheet 6), professional judgment and considering the probability that the metric will indicate deterioration, rank metrics in sheet "EcoSpecs & TPCs" in order of the most sensitive metric expected to detect change (rated 1) to less sensitive to detect change.

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

The different metrics were then ranked, based on FRAI metric group weighting, relative intolerance or sensitivity of the species and professional judgment, as an indication of the expected sensitivity (value) of the metric to detect change. All metrics should be used when monitoring a system, as different indicator species may detect different impacts or changes. The purpose of the ranking of metrics is to provide a rough estimate of metrics most probable (most sensitive) to detect deterioration (species being generally intolerant to changes in their environment should theoretically react earlier to changes/deterioration than more tolerant species, although a more tolerant species will react to a specific impact that may not be detected by more intolerant species). Therefore, although different indicator species may indicate different changes, the ranking aims to highlight which metrics is most likely to be the early indicators of change at the site/reach.

- **Step 5: Complete sheet 3 - Monitoring requirements:** Recommendations were also made regarding monitoring requirements taking into consideration the Ecological Importance and Sensitivity metric, i.e. rare and endangered and unique fish species at the site. The monitoring recommendations included aspects such as frequency of monitoring, optimal sampling season, location (where and which habitats to focus on) as well as sampling techniques (including recommended effort that should be applied). The monitoring recommendation should also be verified and adapted over time once more information becomes available. It is of critical importance that the follow-up monitoring should be conducted during the same season as when baseline surveys were conducted, or TPCs should be refined for the specific season of the monitoring. The more similar the flow (discharge) recorded during monitoring and baseline surveys, the more comparable the results and the more likely changes can be detected (it will exclude natural seasonal and habitat differences at the site, which is coupled with natural variation in fish diversity and abundance at the site).

When a TPC for a certain metric is reached, it must first be established whether that specific habitat type (such as Slow Deep (SD), water column, overhanging vegetation) has been sampled adequately, to exclude the possibility that the TPC was reached as a result of lack of sampling effort. This would therefore mean that sampling should be done when conditions are optimal. Indicator species can be identified before the actual survey at a site and sampling can then be aimed at specific habitats using the most appropriate sampling method that would give the highest probability of the indicator species being sampled if present. The most preferred sampling method for monitoring purposes is electro-fishing, as this method is very effective in especially flow sensitive habitats (e.g. FS) as well as other shallow marginal habitats (such as undercut banks and overhanging vegetation). This method may also be the most reliable of all methods to calculate relative abundance of a species (CPUE). For the purpose of setting EcoSpecs and TPCs during this study, relative abundance was only determined using electro-fishing data and it was expressed as individuals per minute. Electro-fishing however does not have to be the only sampling method applied during the monitoring phase, as sampling methods should be determined by the indicator species, habitat composition, human resources and time availability.

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

2.5 MACROINVERTEBRATES

Adjusted by AR Deacon (original text by R Palmer)

The approach used in this report to define EcoSpecs and TPCs for macroinvertebrates was to define simple rules that could be applied consistently at all sites, and to select metrics based on information that can be readily derived from standard invertebrate biomonitoring data. The EcoSpecs and TPCs recommended here may need to be modified as more biomonitoring data become available. Four components were considered, namely 1) South African Scoring System (SASS) scores, 2) the Macro Invertebrate Response Assessment Index (MIRAI – Thirion, 2007) scores, 3) indicator taxa, and 4) overall compliance.

- **SASS scores:** A hypothetical list of taxa expected to occur under natural conditions was compiled for each EWR site. The list was based on professional judgement and available biomonitoring data for the area. Invertebrate taxa expected to occur at each site with more than 80% probability under natural conditions, were used to generate a likely minimum SASS Total Score and Average Score Per Taxon (ASPT) for natural conditions (A EC). These scores were then used to generate likely site-specific scores for the remaining Categories (B to E), based on the percentage deviation from natural, as indicated in Table 2.6. The likely scores were used as default values for defining Ecological Categories, based on SASS Total Scores and ASPT. The TPCs for SASS5 Total Scores were set 5% higher than the lower boundary of the relevant PES band, while the TPCs for ASPT were set 2% higher than the lowest boundary of the relevant band.

- **MIRAI scores:** The standard MIRAI system was used to generate PES bands, as indicted in Table 2.6. The TPCs were set 5% higher than the lower boundary of the relevant PES band.

Table 2.6 Macroinvertebrate site specific scores for Ecological Categories

Ecological Category	Description	SASS Score (% Total)	ASPT (% Total)	MIRAI Score (%)
A	Natural.	>90	>95	>90
B	Largely Natural.	80 - 89	90 - 95	80 - 89
C	Moderately Modified.	60 - 79	85 - 89	60 - 79
D	Largely Modified.	40 - 59	80 - 84	40 - 59
E	Seriously Modified.	20 - 39	75 - 79	20 - 39
F	Critically Modified.	<20	<75	<20

- **Indicator taxa:** Invertebrate taxa that have been recorded as common or abundant at, or near, each EWR site, and which are sensitive to changes in flow and/or deterioration in water quality, were considered as potential indicators. The selection of indicator taxa was based on recent biomonitoring data collected at or nearby each EWR site. Nearby sites were usually located within the same quaternary catchment as the EWR site. The list was reduced to six taxa, based on their sensitivity to water quality deterioration.
- Tricorythid mayflies were identified as suitable indicator taxa because they are sensitive to flow and water quality deterioration. However, the abundance of these mayflies is usually low during winter, so surveys conducted during winter that fail to record them should not trigger TPCs. This applies to most sites, but not to the lower Orange at EWR O4, where winter water temperature is expected to be high enough for larval numbers not to drop significantly. The following criteria were used to define TPCs for indicator taxa:
  - any one indicator taxon absent for two or more consecutive surveys, except for very common taxa, such as Baetidae and Hydropsychidae, which are expected to always be present, and;
  - more than 50% of the indicator taxa absent on any one survey (i.e. three or more out of six).

- **Overall TPC compliance:** Ten EcoSpecs were selected as suitable monitoring indicators at each site, each with specific TPCs, as explained above. A 70% compliance to the specific TPCs on any one survey was considered acceptable, so the overall TPC for the site should be triggered only when three or more specific TPCs are non-compliant. Full compliance with all ten TPCs on any one monitoring survey is unlikely because of natural variability of river systems.

The most useful sources of information for this report were the following:

- Data collected during the EWR site visits; April to June 2010.
- Data extracted from the National River Health Database.
- Relevant biomonitoring reports.

3 APPROACH AND METHODS: SMALL WEST COAST ESTUARIES

For the purpose of EcoSpec determination for estuaries, the following differentiation is made between EcoSpecs and Resource Quality Objectives (RQOs) (DWS, 2015). EcoSpecs are associated with the Ecological Reserve process and are usually provided per estuary. They are detailed or numerical instream and riparian biota and habitat RQOs as they are quantifiable, measurable, verifiable and enforceable to ensure protection of all components of the resource, which make up ecological integrity (DWA, 2009a). Therefore, EcoSpecs are numerical and can be used for monitoring. 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) and are linked to EcoSpecs. When setting EcoSpecs, the work is usually based on field work that has been undertaken, a monitoring baseline is therefore available and monitoring to determine whether the specifications are being achieved (or Ecological Category) can be undertaken.

If sufficient data is not available to set specifications, broad objectives for the EC are provided only and cannot be used in monitoring as is. Monitoring must be undertaken so that the objectives can be translated into numerical EcoSpecs based on field surveys and the findings of the baseline monitoring.

For the five small West Coast Estuaries, some field work has been undertaken although the process was done at a rapid level and broad EcoSpecs can be provided. Where quantitative information is available, that has been provided.

3.1 FORMAT OF ECOSPECS COMPONENTS

EcoSpecs are set for the short-to medium term (5 to 10 year period) for the following components:

- Overall flow requirement (hydrology).
- Mouth state (hydrodynamics).
- Water quality.
- Characteristics and condition of primary producers (e.g. macrophytes).
- Characteristics and condition of biota (e.g. fish).

Hydrological EcoSpecs are provided as a flow regime associated with the REC for the Buffels, Swartlintjies, Spoeg, Groen and Sout Estuaries with an indication if the various components of the flow regime (baseflows and floods) meet the EWR requirement.

Water quality EcoSpecs were set for all estuaries based on environmental requirements and national guidelines or standards. The water quality component is discussed in Section 3.2.3.

Habitat and biota is described as the habitat and biota associated with a REC. The format of the EcoSpecs is as follows:

- Overall PES, REC.
- PES for each component.
- Ecological objectives for components.

Where the PES does not meet the PERC a "🡅" was used to indicate which individual components should improve to achieve the PERC.

3.2 APPROACH FOLLOWED IN DEVELOPING ESTUARY ECOSPECS

3.2.1 Hydrodynamics

Very little information is available on the hydrodynamics of the small Lower Orange Systems. If an estuary is very sensitive to flow modification (e.g. very small or shallow), and/or in an A or B Category, a ±5% variation was allowed for over a 5-year period. However, if an estuary was deemed to be more robust (e.g. large size, mouth protected) from a flow perspective and/or in a C to F Category, a ±10% variance from the current data set was allowed for over a 5-year period. Where more information was available it was incorporated into the EcoSpecs.

3.2.2 Salinity

Salinity EcoSpecs were derived from measured data or extrapolated for similar systems. Key determining estuarine features used in setting the salinity EcoSpecs were: estuary size, estuary depth, % mouth open and mouth position (i.e. perched/not perched). Data sets used include CSIR Harrison observations and recent field data.

3.2.3 Water Quality

For estuaries, unlike for rivers, there are no official, numerical water quality EcoSpecs specified for various health categories because of the diverse and site-specific nature of many of these variables in estuaries. Based on a general understanding of water quality characteristics in estuaries along this part of the coast, as well as expert knowledge, target ranges were proposed for various water quality health categories, where the condition of any parameter had to be <u>improved</u> (Table 3.1). Otherwise, the present (measured) water quality concentrations were set as EcoSpecs.

Table 3.1 Proposed EcoSpecs for water quality where ecosystem health must be improved to higher category

Variable	Health Category			
	A	B	C	D
Dissolved oxygen (DO)	Average in estuary ≥6 mg/l		Average in estuary ≥4 mg/l	
Turbidity	Site specific, cannot provide generic EcoSpecs			
Dissolved inorganic nitrogen (DIN) in river inflow	50th percentile <0.1 mg/l	50th percentile <0.2 mg/l	50th percentile <0.3 mg/l	50th percentile <0.5 mg/l
Dissolved inorganic phosphate (DIP) in river inflow	50th percentile <0.01 mg/l	50th percentile <0.015 mg/l	50th percentile <0.025 mg/l	50th percentile <0.05 mg/l
Toxic substances	▪ Substance concentrations in estuarine sediment not to exceed targets as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009). ▪ Substance concentrations in estuarine waters not to exceed targets as per SA Water Quality Guidelines for coastal marine waters Department of Water Affairs and Forestry (DWAF, 1995).			

For this study, the water quality EcoSpecs were equated to the corresponding REC allocated to an estuary. Where the PES category for water quality was below the REC category, water quality was identified as a potential risk and the water quality EcoSpecs equivalent to the REC category were proposed. Where the WQ PES category was higher than the REC, the EcoSpecs for the WQ PES were maintained as a precautionary approach until monitoring showed a relation was appropriate.

3.2.4 Macrophytes

The EcoSpecs were set for each estuary based on available data and recent field surveys. Macrophyte EcoSpecs are based on historical data and descriptions and are considered to be of low confidence. Expert opinion and Google images were used to make the assessments. EcoSpecs were generally set to maintain the distribution of current macrophyte habitats (<20% change in the area), maintain the integrity of the riparian zone and floodplain habitat.

3.2.5 Invertebrates

The EcoSpecs were set for each estuary based on analysis of available data and expert opinion informed by first-hand knowledge of the small west coast estuaries. Estuaries sampled by the researchers were roughly grouped into the two brackish and the three systems characterised by cycles of hypersalinity. EcoSpecs were generally set to maintain the diversity, abundance and cyclicity of invertebrate communities, in particular the brine shrimp populations.

3.2.6 Fish

The EcoSpecs were set for each estuary based on analysis of available data and expert opinion informed by first-hand knowledge of small west coast estuaries. Estuaries sampled by the researchers were categorised according to their salinity regime. Preliminary fish lists (% abundance and frequency of occurrence) were based on available information. These fish lists were used to establish EcoSpecs. EcoSpecs are expressed as requirements based on a sampling trip. For example, a requirement that 2 to 5 species should occur in an estuary implies that two to five species should be sampled over successive sampling trips. These EcoSpecs should be further developed and refined as part of the monitoring requirements of individual systems.

3.2.7 Birds

The EcoSpecs were set for each estuary based on analysis of available data and expert opinion informed by first-hand knowledge of small west coast estuaries.

4 APPROACH AND METHODS: ORANGE ESTUARY

EcoSpecs for the Orange Estuary are set based on available data for the short-to medium term (5 to 10 year period) for the following components:

- Overall flow requirement (hydrology).
- Water quality.
- Habitat and biota within estuary

4.1 OVERALL FLOW REQUIREMENT (HYDROLOGY)

The EcoSpecs for water quantity is based on the PERC estuary EWR flow scenario and is provided as a summary of the flow distribution (mean monthly flows in m^3/s) derived from the monthly-simulated data generated for that scenario or slight modifications thereof.

4.2 WATER QUALITY

In addition to the quality of river inflow, water quality in estuaries is also affected by other external sources, namely:

- Seawater quality entering the estuary
- Wastewater inputs directly into the estuary.

EcoSpecs for Water Quality sets concentration limits for water quality constituents in river inflow so as to ensure that the estuary is protected. In addition, concentration limits should also be set for waste discharges directly into the estuary and seawater quality. The DWS has sole administrative control over water quality matters in rivers and land-derived wastewater discharges. For discharges into the sea and estuaries, several other statutes may also apply, including those administered by Department of Environment Affairs and Provincial authorities (Table 4.1).

Table 4.1 Important statutes relevant to management and protection of water quality, particularly at sea and in estuaries (CSIR, 1991)

Statutes	Administrative Authority
Marine Living Resources Act (Act 18 of 1998)	Department of Environment Affairs
Dumping at sea control Act (No. 73 of 1980)	
Environmental Conservation Act (No. 73 of 1989)	
National Environmental Management Act (No. 107 of 1998)	
National Environmental Management: Integrated Coastal Management Act (No 24 of 2008)	
Prevention and combating of pollution of the sea by oil Act (No. 6 of 1981)	Department of Transport
International convention for prevention of pollution from Ships Act (No. 2 of 1986)	
International convention relating to intervention on the high seas in cases of oil pollution Act (No. 64 of 1987)	
Cape and Kwazulu Natal Conservation Ordinances	Provincial Nature Conservation agencies
Harbour Regulations	National Ports Authority

To facilitate integration between the river's and estuarine components the following approach should be followed in setting EcoSpecs for Water Quality, specifically the quality of river inflow entering at the head of the estuary:

- Obtain the EcoSpecs for Water Quality from the river resource unit just upstream of the estuary (this would specify the water quality at the end of that resource unit, and would therefore be representative of the river water entering the estuary)
- Assess the implications of these water quality parameters on the different **biotic** components by applying the **Estuary Health Index**
- If the estuary remains in the recommended Ecological Category (or selected Ecological Class, if this had been determined) the **Water Quality EcoSpecs (and TPCs) for the river is accepted for the estuary**. If not, these need to be adjusted so as to meet requirements.

4.3 ECOSPECS FOR HABITAT AND BIOTA WITHIN ESTUARY

EcoSpecs and associated TPCs for habitat and biota include the following components within the estuary:

- Abiotic components within the estuary (hydrodynamics, sediment dynamics and water quality)
- Biotic components (microalgae, macrophytes, invertebrates, fish and birds).

It is important to note that there are also other statues that can set objectives for estuaries. Examples are listed in Table 4.2.

Table 4.2 Important statutes relevant to management and protection of habitat and biota

Statutes	Administrative Authority
Marine Living Resources Act (Act 18 of 1998)	Department of Environment Affairs
National Environmental Management Act (No. 107 of 1998)	
National Environmental Management: Integrated Coastal Management Act (No 24 of 2008)	
Integrated Environmental Management: Protected Areas Act (No. 57 of 2007)	
Integrated Environmental Management : Biodiversity Act (No. 10 of 2004)	
Local Government: Municipal Systems Act (No. 32 of 2000)	Department of Provincial & Local Government

The EcoSpecs (and TPCs) for abiotic components cannot be set independently of the biota, as the EcoSpecs for the abiotic components is largely a reflection of the 'habitat requirements' necessary to maintain the different Biotic Components as per the PERC. To illustrate this, some examples are listed below:

Abiotic Component	EcoSpecs	Threshold of Potential Concern
Water quality	Salinity intrusion should not cause exceedence of TPCs for fish, invertebrates, macrophytes and microalgae (see above).	Salinity greater than … ppt for longer than 3 months at ..km upstream from the mouth (this would have an impact on the brackish saltmarsh, reeds and sedges and invertebrates). Salinity greater than … ppt occurs above … km upstream of the mouth (this would have an impact on fish).
Hydrodynamics	Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	River inflow below … m^3/s persist for longer than 4 months.

Abiotic Component	EcoSpecs	Threshold of Potential Concern
Sediment dynamics	Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota.	River inflow distribution patterns (flood components) differ by more than 10% (in terms of magnitude, timing and variability) from that of the Present State.

The EcoSpecs (and TPCs) for biotic components, should describe the health status of the Biotic Component as per the PERC. To illustrate this, some examples are listed below:

Component	EcoSpecs	Threshold of Potential Concern
Microalgae	Maintain high subtidal benthic microalgal biomass during the closed mouth phase and low intertidal benthic microalgal biomass during the open phase.	Deviation in benthic microalgal biomass by .. % compared with Present State concentrations. No brackish epipelic diatoms are found during the closed phase.
Macrophytes	Maintain the distribution of plant community types i.e. Submerged macrophyte, Ruppia cirrhosa beds during closed mouth brackish conditions (~… ha), salt marsh, Sarcocornia perennis marsh during open mouth conditions (~… ha), Phragmites australis stands in the middle / upper reaches (~0…. ha) and salt marsh grasses (~…. ha).	Greater than … % change in the area covered by different plant community types for baseline open and closed mouth conditions.
Fish	Retain the following fish assemblages in the estuary (based on abundance): estuarine species (….%), estuarine associated marine species (…..%) and indigenous freshwater species (…..%). All numerically dominant species are represented by 0+ juveniles.	Level of estuary associated marine species drops below ….% of total abundance. Level of estuarine species increases above ….% of total abundance. Levels of Mozambique tilapia increases above …% of total abundance. Absence of 0+ juveniles of any of the dominant fish species.

5 EWR O3 (AUGRABIES): ECOSPECS AND TPCs

A summary of the site EcoClassification results is provided below (DWS, 2016b).

Table 5.1 EWR O3: EcoClassification results

EWR O3 (AUGRABIES)

EIS: HIGH
Highest scoring metrics are instream and riparian rare /endangered biota, unique instream and riparian biota, taxon richness of riparian biota, diversity of riparian habitat types, critical riparian habitat, refugia, migration corridor, National Park.

PES: C
Decrease in large flood frequency. Agricultural return flows, agricultural activities and associated water quality impacts.
Higher low flows than natural in the dry season, drought and dry periods. Decreased low flows at other times. The presence of alien fish and vegetation species. Barrier effect of dams. Decreased sedimentation.

REC: B
Reinstate droughts (i.e., lower flows than present during the drought season).Improve (higher) wet season base flows.
Clear alien vegetation. Improve agricultural practices.

Driver Components	PES	TREND	REC
IHI HYDROLOGY	E		
WATER QUALITY	C		C
GEOMORPHOLOGY	C	0	C
INSTREAM IHI	D		
RIPARIAN IHI	C/D		
Response Components	**PES**	**TREND**	**REC**
FISH	C	0	B
MACRO INVERTEBRATES	C	0	B
INSTREAM	C	0	B
RIPARIAN VEGETATION	B/C	-	B
RIVERINE FAUNA	C	0	B
ECOSTATUS	C	0	B
EIS	HIGH		

The PERC for the components for which EcoSpecs are set are provided in Table 5.2. Note that the estimated changes for the EcoSpecs associated with a post dam development scenario are also provided.

Table 5.2 EWR O3: PERC

Driver components	PES	REC	Pre-Dam recommendation PERC (Sc A2; A3)	Post-Dam recommendation D Scenarios*
Physico chemical	C	C	B/C	B
Fish	C	B	B/C	B
Invertebrates	C	B	B/C	B/C
Riparian vegetation	B/C	B	B/C	B/C
EcoStatus	C	B	B/C	B/C

* Further investigations are necessary on dam sizes to finalise the post-dam scenario recommendations. However, as the differences between the D and C Scenarios are relatively small, an indication of EcoSpecs and TPCs associated with the D scenarios (small dam) has been provided. This will be updated during the Classification study that will folllow.

EcoSpecs and TPCs for EWR O3 are provided for the different components in Section 5.1 to 5.5.

5.1 WATER QUALITY

The EcoSpecs and TPCs for water quality (Table 5.3) are provided below.

Table 5.3 EWR O3: Water quality EcoSpecs and TPCs (PES: C; PERC: B/C, Post Dam Sc: B)

Water quality metrics	EcoSpecs	TPC
Inorganic salts$^{(*)}$		
$MgSO_4$	The 95th percentile of the data must be ≤ 16 mg/L.	The 95th percentile of the data is 13 - 16 mg/L.
Na_2SO_4	The 95th percentile of the data must be ≤ 20 mg/L.	The 95th percentile of the data is 16 - 20 mg/L.
$MgCl_2$	The 95th percentile of the data must be ≤ 15 mg/L.	The 95th percentile of the data is 12 - 15 mg/L.
$CaCl_2$	The 95th percentile of the data must be ≤ 21 mg/L.	The 95th percentile of the data is 17 - 21 mg/L.
NaCl	The 95th percentile of the data must be ≤ 45 mg/L.	The 95th percentile of the data is 36 - 45 mg/L.
$CaSO_4$	The 95th percentile of the data must be ≤ 351 mg/L.	The 95th percentile of the data is 280 - 351 mg/L.
Physical variables		
Electrical Conductivity	The 95th percentile of the data must be ≤ 55 mS/m.	The 95th percentile of the data is 44 - 55 mS/m.
pH	The 5th percentile of the data must range from 6.5 to 8.0, and the 95th percentile from 8.0 to 8.8.	The 5th percentile of the data is <6.7 and >7.8, and the 95th percentile is <8.2 and >8.6.
Temperature	Some minor man-made changes to the river but no known changes to the natural temperature regime.	Rely on biotic response data to evaluate whether the TPC for temperature is being reached. Some highly temperature sensitive species are at lower abundances and frequency of occurrence than expected for reference.
Dissolved oxygen	The 5th percentile of the data must be ≥8 mg/L.	The 5th percentile of the data is <8.2 mg/L.
Turbidity	Vary by a small amount from the natural turbidity range. Minor silting of instream habitats is acceptable.	Silting of habitats. Check biotic response for habitat-related changes.
Nutrients		
Total Inorganic Nitrogen (TIN-N)	The 50th percentile of the data must be ≤ 0.25 mg/L.	The 50th percentile of the data must be 0.2 - 0.25 mg/L.
PO_4-P	**PES:** The 50th percentile of the data must be ≤ 0.125 mg/L. **PERC & Post-Dam:** The 50th percentile of the data must be ≤ 0.025 mg/L.	**PES:** The 50th percentile of the data must be 0.06 - 0. 075 mg/L $^{(**)}$. **PERC & Post-Dam:** The 50th percentile of the data must be 0.02 - 0. 025 mg/L.
Response variables		
Chl-*a* phytoplankton	**PES:** The 50th percentile of the data must be ≤ 20 µg/L$^{(\#)}$. **PERC & Post-Dam:** The 50th percentile of the data must be ≤ 15 µg/L.	**PES:** The 50th percentile of the data must be 16 – 20 µg/L$^{(\#)}$. **PERC & Post-Dam:** The 50th percentile of the data must be 12 - 15 µg/L.
Chl-*a* periphyton	**PES:** The 50th percentile of the data must be ≤ 21 mg/m$^{2\ (\#)}$. **PERC & Post-Dam:** The 50th percentile of the data must be ≤ 12 mg/m^2.	**PES:** The 50th percentile of the data must be 17 – 21 mg/m$^{2(\#)}$. **PERC & Post-Dam:** The 50th percentile of the data must be 10 - 12 mg/m^2.
Toxics		
Toxics, other than Aluminium	The 95th percentile of the data must be within the CEV as stated in DWAF (1996a)$^{(\#\#)}$.	An impact is expected if the 95th percentile of the data exceeds the TWQR as stated in DWAF (1996a).
Aluminium	**PES:** The 95th percentile of the data must be	**PES:** The 95th percentile of the data must

Water quality metrics	EcoSpecs	TPC
	≤ 0.105 mg/L. **PERC & Post-Dam**: The 95th percentile of the data must be ≤ 0.0625 mg/L.	be 0.084 - 0.105 mg/L. **PERC & Post-Dam:** The 95th percentile of the data must be 0.05 - 0.0625 mg/L.

(*) To be generated using TEACHA when the TPC for Electrical Conductivity is exceeded or salt pollution is expected. Should the TPC for any integrated salt be exceeded, 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.
(**) Although the upper boundary for the relevant phosphate category is 0.125 mg/L, the TPC has been set at 0.075 mg/L as the PES measurements (50th percentile) were 0.029 mg/L (i.e. a recalibrated A/B Category).
(#) Low confidence. EcoSpec and TPC boundaries may need adjusting as data become available.
(##) Although category boundaries exist in the Water quality Reserve manual (DWAF, 2008) for a number of toxicants, adherence to the CEV (DWAF, 1996a) is recommended for the present state. Data collection and testing will need to be undertaken to assess the suitability of these objectives.

There is some indication of elevated nutrient levels throughout the reach; probably due to intensive agricultural activities in the area. The presence of toxic algae has been reported in the Lower Orange River passing Upington, as well as intermittently high concentrations of some metals, i.e. aluminium, cadmium, copper and lead, in the Upington and Neusberg weir area.

Note that due to the paucity of toxics data, no further EcoSpecs or TPCs can be provided with any confidence for the scenarios. Toxics concentrations are expected to drop under the scenarios due to higher flows and dilution in the system, with conditions under the post-dam EC being slightly better than the PERC. Until more data are available for toxics, assessments of improved state should revert to instream biota as indicators of water quality.

5.2 DIATOMS

Site specific diatom data were available from sample collection during 2008 – 2010 and 2015 across the reach from Augrabies to Vioolsdrift, along with measured *in situ* water quality measurements.

The biological water quality remained relatively stable at a C EC during 2008, 2010, and 2015 with a slight improvement in 2009 to a B/C EC. Although elevated at times organic pollution did not seem to be a major problem in this reach, although levels were elevated during 2010. Nutrients were elevated for all sampling years indicating continuous impact, probably due to intensive agricultural activities in the area. Salinity was problematic at times. Valve deformities were only noted in 2015, suggesting that metal toxicity was present at the time of sampling.

A summary of diatom data collected at EWR O3 is provided in Table 5.4. The EcoSpecs and TPCs for this reach were set at a C Category and provided in Table 5.5.

Table 5.4 EWR O3: Summary of available diatom results

Sample date	SPI	PTV (%)	EC
May 2008	12.7	2.7	C
August 2009	14.4	3.0	B/C
June 2010	13.3	11.5	C
June 2015	13.9	0.0	C

Table 5.5 EWR O3: Diatom EcoSpecs and TPCs (C PES)

Metric and associated indicator group/species	Indicator species	EcoSpec	TPC	General comment
SPI score	N/a	12 – 14	11 - 12	The diatom-based water quality for this site should fall within a C Category. If thresholds are exceeded during consecutive low and high flow water quality deterioration should be deemed as serious and impacts should be substantiated with water quality analysis and available data.
PTVs (%)	N/a	<10	>10	PTV scores were generally low indicating that organic pollution levels are generally low. If thresholds are exceeded during consecutive low and high flow this metric should be flagged.
Valve deformities (%)	N/a	<2	>2	A check should be done for valve deformities with every count as this is indicative of metal contamination. If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken to determine the presence of metal toxicity.
Oxygenation				
Achnathidium spp. abundance (% of total count)	Associated with elevated flows. The genus generally prefers good water quality with high oxygenation rates (Taylor *et al*., 2007b). Species that should be included in count: *A. minutissima, A. biasolettianum,A. pyrenaicum* and *A. rivulare*	>2	<2	During high/elevated flow this genus must be present and is an important indicator of system recovery. Species should not be absent in more than one high flow sample. If absent, water quality analysis should be undertaken.
Encyonopsis spp. abundance (% of total count)	Cosmopolitan species found in calcareous waters with moderate electrolyte content. Requires an oxygen rich environment (Taylor *et al*., 2007b). Species that should be included in count: *E. minuta, E. microcephala* and *E. leei* var. *sinensis.*	>1	<1	This genus should be present in high and low flow samples. If absent during three consecutive samples, water quality analysis should be undertaken.
Nutrients				
Cocconeis spp. abundance (% of total count)	The genus *Cocconeis* has a broad ecological range and is found in most running waters except where nutrients are low or acidic conditions prevail (Taylor *et al*., 2007b). This genus is tolerant of moderate organic pollution and also extends into brackish waters. It is abundant on rocks, but is also found on other surfaces such as filamentous algae and macrophytes (Kelly *et al*., 2001). According to Fore and Grafe (2002), *C. placentula* prefer alkaline, eutrophic conditions. Species that should be included in count: *C. placentula, C. pediculus* and *C. placentula* var. *euglypta.*	<5	>5	If thresholds are exceeded during consecutive low and high flow this variable should be flagged.
Nitzschia frustulum abundance (% of total count)	According to Cholnoky (1968) *N. frustulum* is considered a nitrogen heterotroph and Hecky and Kilham (1973) state that it is extremely tolerant of salinity and high alkalinity, and becomes abundant in brackish waters because competition from other diatom species is reduced. It is tolerant of critical levels of pollution (Taylor *et al*., 2007b).	<3	>3	
Organics				

Metric and associated indicator group/species	Indicator species	EcoSpec	TPC	General comment
Amphora pediculus abundance (% of total count)	A cosmopolitan species found in waters with a moderate electrolyte content and tolerating critical levels of pollution (Taylor *et al.*, 2007b).	<1	>1	If thresholds are exceeded during consecutive low and high flow this metric should be flagged.
Gomphonema parvulum abundance (% of total count)	Indicates organic enrichment, which is usually associated with sedimentation, both organic and inorganic sediment (Teply & Bahls, 2006).	<5	>5	
Eolimna spp. abundance (% of total count)	Pioneer species ('r-strategists') that colonise bare surfaces and occur in greater abundance with the onset of organic pollution while the community would shift to a dominance of *Sellaphora seminulum* as the community adjusts to the organic pollution levels. Species that should be included in count: *E. minima* and *E. subminuscula*.	<10	>10	
Sellaphora spp. abundance (% of total count)"	*Sellaphora seminulum*: Succession occurs in established communities as a result of changes in the physico-chemical environment (Weitzel, 1979). The community would shift to a dominance of *S. seminulum* as the community adjusts to the organic pollution levels and would also be dominant throughout sampling if organic pollution is continual.	<10	>10	
Salinity				
Cyclostephanos spp. abundance (% of total count)	In North America, smaller species of *Cyclostephanos* often dominate the plankton flora during spring and summer in nutrient rich lakes and rivers. Many of the species are tolerant of elevated levels of total dissolved solids and are present in highly calcareous or saline waters (Spaulding and Edlund, 2008). Species that should be included in count: *C. dubius* and *C. invisitatus*.	<10	>10	If thresholds are exceeded during consecutive low and high flow this metric should be flagged.
Stephanodiscus spp. abundance (% of total count)	Occur in waters with elevated electrolyte content. Species that should be included in count: *S. agassizensis*, *S. minutulus* and *S. hantzschii.*	<5	>5	
Nitzschia dissipata abundance (% of total count)	Indicates hard water (calcium based salinity), and favours alkaline conditions and waters of moderate to high electrolyte content (Taylor, *et al.*, 2007b.). Not present in waters of low electrolyte content. The dominance of this species indicates the possible increase in salinity levels.	<10	>10	
Pseudostaurosiropsis geocollegarum abundance (% of total count)	Seems to prefer more alkaline waters (pH 7.1 - 8.3), higher conductivity (458 - 1120 µS/cm), and more eutrophic conditions (early eutrophic to dystrophic) (Morales, 2002).	<10	>10	
Turbidity				
Stephanodiscus agassizensis abundance (% of total count)	A planktonic species found in eutrophic rivers and lakes with an elevated electrolyte concentration and turbidity (Taylor *et al.*, 2007b)	<2.5	>2.5	If thresholds are exceeded during consecutive low and high flow this metric should be flagged.

5.3 RIPARIAN VEGETATION

The EcoSpecs and TPCs for riparian vegetation (Table 5.6) are provided below.

Table 5.6 EWR O3: Riparian vegetation EcoSpecs and TPCs (PES, PERC and Post Dam Sc: B/C)

Component	EcoSpec: PES, PERC and Post Dam (B/C)	TPC: PES, PERC and Post Dam (B/C)
Riparian zone		
Alien Invasion (perennial aliens)	Alien species cover less than 15%.	An increase in alien species cover above 15%.
Marginal Zone		
Terrestrialisation	The absence of terrestrial woody species.	A presence of terrestrial woody species.
Indigenous Riparian Woody Cover	Indigenous riparian woody cover between 5 - 60%.	A decrease in riparian woody species cover below 5% OR an increase above 60%.
P. australis (reed) cover	Reed cover below 40%.	An increase in reed cover above 40%.
Lower Zone		
Terrestrialisation	Maintain terrestrial woody species cover less than 5%.	An increase in terrestrial woody species cover above 5%.
Indigenous Riparian Woody Cover	Indigenous riparian woody cover between 10 - 50%.	A decrease in riparian woody species cover below 10% OR an increase above 50%.
P. australis (reed) cover	Reed cover below 40%.	An increase in reed cover above 40%.
Upper Zone		
Terrestrialisation	Maintain terrestrial woody species cover less than 20%.	An increase in terrestrial woody species cover above 20%.
Indigenous Riparian Woody Cover	Indigenous riparian woody cover between 30 - 70%.	A decrease in riparian woody species cover below 30% OR an increase above 70%.
MCB		
Terrestrialisation	Maintain terrestrial woody species cover less than 20%.	An increase in terrestrial woody species cover above 20%.
Indigenous Riparian Woody Cover	Indigenous riparian woody cover above 40%.	A decrease in riparian woody species cover below 40%.

5.4 FISH

EcoSpecs and TPCs for FRAI data are provided in Table 5.7 for a PES of a C and a B for post-dam scenarios and B/C for the PERC. The spatial FROC of EWR O3 is provided in Table 5.8 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

Table 5.7 EWR O3: Fish EcoSpecs and TPCs (PES: C; Post-Dam Sc: B; PERC: B/C)

Indicator	PES (C)				
	EWR Site			Reach	
	EcoSpecs	TPC (Biotic)	TPC (Habitat)	Indicator Spp.	TPC (Biotic)
Rank 1. Species richness					
All Indigenous species	**Eight (8)** of the expected (under reference conditions) 12 indigenous fish species were sampled during the baseline (EWR) survey.	**Less than 7** fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity - depth categories and cover features.	All indigenous spp.	Baseline (PES) FRAI score of 77% (high 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 68.4% low C).
Rank 2. Relative abundance					
N/a	During baseline (EWR) surveys fish were sampled at **0.7** individuals per minute using a SAMUS electrofisher (wading and from boat). Relative abundance was very low.	Relative abundance of **less than 0.5** individual per minute sampled at the site (during same season as baseline data) when habitat can be sampled efficiently and using comparable method.	N/a	N/a	N/a
Rank 9. Any alien/introduced fish species					
Any alien/ introduced spp.	One indigenous introduced fish species (OMOS) was sampled at the site during the baseline EWR survey at 0.12 ind/min.	Present of any additional alien/introduced species at site, or OMOS present at relative abundance > 0.2 ind/min.	N/A	Any alien/introduced spp.	CCAR, GAFF and introduced OMOS previously sampled in reach. Presence of any additional alien/introduced species.
Rank 3: FD habitats, substrate, flow dependant spp. (flow alteration)					
BAEN LCAP	BAEN and LCAP were sampled at the site during the baseline EWR surveys. BAEN was present at 0.1 ind/min while LCAP was present at 0.2 ind/min.	BAEN and/or LCAP absent during any survey **OR** present at relative abundance of <0.05 ind/min for BAEN or <0.1 ind/min for LCAP.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates, Increased sedimentation of	LCAP BAEN	Any decreased FROC in reach of LCAP and BAEN (refer to sheet 5 - FROC, column F: Table 2).

Indicator	PES (C)				
	EWR Site			Reach	
	EcoSpecs	TPC (Biotic)	TPC (Habitat)	Indicator Spp.	TPC (Biotic)
			riffle/rapid substrates, excessive algal growth on substrates.		
Rank 3: FS habitats					
BAEN BKIM	The two indicator species of this metric group, BAEN and BKIM were sampled at the site during the baseline EWR surveys. BAEN was present at 0.1 ind/min while BKIM was very scarce at 0.01 ind/min.	BAEN absent during any survey , BKIM absent during 2 consecutive surveys (>50% of time) **OR** BAEN present at relative abundance of <0.05 ind/min.	Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows) (to be quantified with RHAM).	BAEN BKIM	Any decreased FROC in reach of BAEN and BKIM (refer to sheet 5 - FROC, column F: Table 2)
Rank 3: Water quality intolerance					
BKIM LCAP	These two indicator species of this metric group were sampled at the site during the baseline EWR surveys. BKIM was very scarce at 0.01 ind/min while LCAP was present at 0.2 ind/min.	LCAP absent during any survey, BKIM absent during 2 consecutive surveys (>50% of time) **OR** present at relative abundance of <0.1 ind/min for LCAP.	Decreased water quality	BKIM LCAP	Any decreased FROC in reach of BKIM and LCAP (refer to sheet 5 - FROC, column F: Table 2).
Rank 4: SD habitats					
LCAP CGAR	These two indicator species of this metric group were sampled at the site during the baseline EWR surveys. BKIM was very scarce at 0.01 ind/min while LCAP was present at 0.2 ind/min.	LCAP absent during any survey, CGAR absent during 2 consecutive surveys (>50% of time) **OR** present at relative abundance of <0.1 ind/min for LCAP.	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools).	LCAP CGAR	Any decreased FROC in reach of LCAP and CGAR (refer to sheet 5 - FROC, column F: Table 2).
Rank 5: Water column					
MBRE BAEN	These two indicator species of this metric group were sampled at the site during the baseline EWR surveys. BAEN was present at 0.1 ind/min while MBRE was very scarce at 0.18 ind/min.	BAEN and/or MBRE absent during any survey **OR** present at relative abundance of <0.05 ind/min for BAEN or <0.15 ind/min for LCAP.	Reduction in suitability of water column (i.e. increased sedimentation of pools)	MBRE BAEN	Any decreased FROC in reach of MBRE and BAEN (refer to sheet 5 - FROC, column F: Table 2).

Indicator	PES (C)				
	EWR Site			Reach	
	EcoSpecs	TPC (Biotic)	TPC (Habitat)	Indicator Spp.	TPC (Biotic)
Rank 6: SS habitats					
PPH MBRE	These two indicator species of this metric group were sampled at the site during the baseline EWR surveys. PPHI was present at 0.03 ind/min while MBRE was very scarce at 0.18 ind/min.	PPHI **and/or** MBRE absent during any survey **OR** present at relative abundance of <0.01 ind/min for PPHI or <0.15 ind/min for MBRE.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).	PPHI MBRE	Any decreased FROC in reach of PPHI and MBRE (refer to sheet 5 - FROC, column F: Table 2).
Rank 7: Over - hanging vegetation					
PPHI BPAU	These two indicator species of this metric group (in the absence of TSPA at the site) were sampled at the site during the baseline EWR surveys. PPHI was present at 0.03 ind/min while BPAU was very scarce at 0.01 ind/min.	PPHI **and/or** BPAU absent during any survey **OR** present at relative abundance of <0.01 ind/min for PPHI or <0.01 ind/min for BPAU.	Significant change in overhanging vegetation habitats (e.g. overgrazing, vegetation removal, alien vegetation encroachment, and erosion).	PPHI TSPA	Any decreased FROC in reach of PPHI and TSPA (refer to sheet 5 - FROC, column F: Table 2).
Rank 8: Undercut banks					
PPHI	With ASCL not sampled at the EWR site during the baseline survey, PPHI is the only indicator species of this metric. PPHI was present at 0.03 ind/min.	PPHI absent during any survey **OR** present at relative abundance of <0.01 ind/min for PPHI.	Significant change in undercut bank habitats (e.g. bank erosion, reduced flows).	PPHI ASCL	Any decreased FROC in reach of PPHI and ASCL (refer to sheet 5 - FROC, column F: Table 2).
Rank 8: Instream vegetation					
BPAU	With TSPA not sampled at the EWR site during the baseline survey, BPAU is the only indicator species of this metric. BPAU was very scarce at 0.01 ind/min.	BPAU absent during any survey **OR** present at relative abundance of <0.01 ind/min for BPAU	Significant change in instream vegetation (e.g. flow modification, water quality deterioration, especially increased turbidity).	TSPA BPAU	Any decreased FROC in reach of TSPA and BPAU (refer to sheet 5 - FROC, column F: Table 2).

Table 5.8 EWR O3: Spatial FROC under reference, PES conditions (C), PERC (B/C), Post-Dam Sc (B = REC) and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC				
		Reference (A)	PES: C		PERC: B/C EC	Post-Dam: B EC
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/ derived FROC	Expected/ derived FROC
Indigenous species						
ASCL	*Austroglanis sclateri* (Boulenger, 1901)	2	1	0	1.4	1.5
BAEN*	*Labeobarbus aeneus* (Burchell, 1822)	4	3	2	3.3	3.5
BHOS	*Barbus hospes* (Barnard, 1938)	3	1.5	0	1.8	2
BKIM*	*Labeobarbus kimberleyensis* (Gilchrist & Thompson, 1913)	3	2	1	2.4	2.5
BPAU*	*Barbus paludinosus* (Peters, 1852)	3	2	1	2.1	2.5
BTRI*	*Barbus trimaculatus* (Peters, 1852)	3	2.5	1.5	2.5	2.5
CGAR*	*Clarias gariepinus* (Burchell, 1822)	4	3.5	2.5	3.5	3.5
LCAP*	*Labeo capensis* (Smith, 1841)	5	4	3	4.0	4
LUMB	*Labeo umbratus* (Smith, 1841)	1	0.5	0	0.5	0.5
MBRE*	*Mesobola brevianalis* (Boulenger, 1908)	4	3.5	2.5	3.5	3.5
PPHI*	*Pseudocrenilabrus philander* (Weber, 1897)	4	3	2	2.5	3
TSPA	*Tilapia sparrmanii* (Smith, 1840)	4	3	2	2.5	3
Introduced species						
OMOS*	*Oreochromis mossambicus* (Peters, 1852)	0	4	5	2	0

* Sampled at EWR site during baseline survey (June 2010).

5.5 MACROINVERTEBRATES

5.5.1 SASS data

Available SASS5 data collected at or near Site EWR O3 are summarised in Table 5.9.

Table 5.9 EWR O3: Available SASS 5 data

Site	Date	SASS Score	ASPT	No. of Taxa	Reference
D7ORAN-NEUSB	13-Oct-2004	53	5.3	10	Ramogale Sekwele (River Health Database)
D8ORAN-BLOUP	13-Oct-2004	59	4.9	12	Ramogale Sekwele (River Health Database)
D8ORAN-BLOUP	20-Apr-2005	75	5.8	13	Ramogale Sekwele (River Health Database)
D8ORAN-ONSEE	20-Apr-2005	55	3.7	15	Ramogale Sekwele (River Health Database)
D7ORAN-NEUSB	23-Nov-2005	106	5.3	20	Ramogale Sekwele (River Health Database)
D8ORAN-BLOUP	23-Nov-2005	113	5.1	22	Ramogale Sekwele (River Health Database)
D8ORAN-ONSEE	23-Nov-2005	88	4.9	18	Ramogale Sekwele (River Health Database)
EWR O3	29-May-2010	133	6.7	20	This study

5.5.2 Indicator taxa

Baetidae (>2 spp.), Leptophlebiidae, Tricorythidae, Atyidae, Elmidae, and Leptoceridae were selected as monitoring indicators for EWR O3. Table 5.10 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 5.10 EWR O3: Habitat preference of macroinvertebrate indicator taxa

Habitat metrics	Baetidae	Leptophlebiidae	Tricorythidae	Atyidae	Elmidae	Leptoceridae
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)						
Moderate (SASS 7 - 10)	10	9	9	8	8	
Low (SASS 4 - 6)						6

5.5.3 EcoSpecs and TPCs

EcoSpecs and TPCs for the PES at EWR O3 are provided in Table 5.11.

Table 5.11 EWR O3: Macroinvertebrate EcoSpecs and TPCs (PES: C)

EcoSpecs	TPCs
SASS5 Score between 143 and 161.	SASS5 Score < 150.
ASPT between 5.9 and 6.3.	ASPT < 6.1.
MIRAI Score between 60% and 79%.	MIRAI Score < 63%.
At least 50% indicator taxa present.	Three or more Indicator Taxa absent.
Indicator Taxa	
Baetidae >2 spp.	Baetidae < 2 spp on any one survey.
Leptophlebiidae present.	Leptophlebiidae absent on two or more consecutive surveys.
Tricorythidae present (except winter).	Tricorythidae absent on two or more consecutive surveys.
Atyidae present.	Atyidae absent on two or more consecutive surveys.
Elmidae present.	Elmidae absent on two or more consecutive surveys.
Leptoceridae present.	Leptoceridae absent on two or more consecutive surveys.

The EcoSpecs and TPCs for macroinvertebrates, based on a B/C for the PERC and Post-Dam scenarios are provided in Table 5.12.

Table 5.12 EWR O3: Macroinvertebrate EcoSpecs and TPCs (PERC and Post-Dam Sc: B/C)

EcoSpecs	TPCs
SASS5 Score between 150 and 165.	SASS5 Score < 155.
ASPT between 6.0 and 6.8.	ASPT < 6.3.
MIRAI Score between 70% and 85%.	MIRAI Score < 73%.
At least 60% indicator taxa present.	Two or more Indicator Taxa absent.
Indicator Taxa	
Baetidae >2 spp.	Baetidae < 2 spp on any one survey.
Leptophlebiidae present.	Leptophlebiidae absent on any one survey.
Tricorythidae present (except winter).	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.
Leptoceridae present.	Leptoceridae absent on two or more consecutive surveys.

6 EWR O4 (VIOOLSDRIFT): ECOSPECS AND TPCs

A summary of the site EcoClassification results are provided below (DWS, 2016b).

Table 6.1 EWR O4: EcoClassification results

<table>
<tr><th colspan="2">EWR O4 (VIOOLSDRIFT)</th></tr>
<tr><td rowspan="14">EIS: HIGH
Highest scoring metrics are instream and riparian rare /endangered biota, unique instream and riparian biota, migration corridor, Transfortier Park in the MRU[1].

PES: B/C
Decreased large flood frequency. Agricultural return flows and mining activities – water quality problems. Higher low flows than natural in the dry season, drought and dry periods.
Decreased low flows at other times. The presence of alien fish and vegetation species. Barrier effect of dams. Decreased sedimentation due to upstream dams and lack of large floods.

REC:
Improved (higher) wet season base flows. Clear alien vegetation. Control grazing and trampling.</td>
<td>
<table>
<tr><th>Driver Components</th><th>PES</th><th>TREND</th><th>REC</th></tr>
<tr><td>IHI HYDROLOGY</td><td>D</td><td></td><td></td></tr>
<tr><td>WATER QUALITY</td><td>C/D</td><td></td><td>C/D</td></tr>
<tr><td>GEOMORPHOLOGY</td><td>C</td><td>0</td><td>C</td></tr>
<tr><td>INSTREAM IHI</td><td>D</td><td></td><td></td></tr>
<tr><td>RIPARIAN IHI</td><td>D</td><td></td><td></td></tr>
<tr><th>Response Components</th><th>PES</th><th>TREND</th><th>REC</th></tr>
<tr><td>FISH</td><td>C</td><td>0</td><td>B/C</td></tr>
<tr><td>MACRO INVERTEBRATES</td><td>C</td><td>0</td><td>B/C</td></tr>
<tr><td>INSTREAM</td><td>C</td><td>0</td><td>B/C</td></tr>
<tr><td>RIPARIAN VEGETATION</td><td>C</td><td>-</td><td>B</td></tr>
<tr><td>RIVERINE FAUNA</td><td>C</td><td>-</td><td>B/C</td></tr>
<tr><td>ECOSTATUS</td><td>C</td><td>-</td><td>B/C</td></tr>
<tr><td>EIS</td><td colspan="3">HIGH</td></tr>
</table>
</td></tr>
</table>

1 Management Resource Unit.

The PERC for the components for which EcoSpecs are set are provided in Table 6.2. Note that the estimated changes for the EcoSpecs associated with a post dam development scenario are also provided.

Table 6.2 EWR O4: PERC

Driver components	PES	REC	Pre-Dam recommendation PERC (Sc A2; A3)	Post-Dam recommendation D Scenarios*
Physico chemical	C/D	C/D	C	C
Fish	C	B/C	C	B/C
Invertebrates	C	B/C	B/C	B/C
Riparian vegetation	C	B	B/C	B/C
EcoStatus	C	B/C	B/C	B/C

* Further investigations are necessary on dam sizes to finalise the post-dam scenario recommendations. However, as the differences between the D and C Scenarios are relatively small, an indication of EcoSpecs and TPCs associated with the D scenarios (small dam) has been provided. This will be updated during the Classification study that will folllow.

EcoSpecs and TPCs for EWR O4 are provided for the different components in Section 6.1 to 6.5.

6.1 WATER QUALITY

The EcoSpecs and TPCs for water quality (Table 6.3) are provided below.

Table 6.3 EWR O4: Water quality EcoSpecs and TPCs (PES: C/D; PERC and Post-Dam Sc: C)

Water quality metrics	EcoSpecs	TPC
Inorganic salts(*)		
$MgSO_4$	The 95th percentile of the data must be ≤ 16 mg/L.	The 95^{th} percentile of the data is 13 - 16 mg/L.
Na_2SO_4	Calculate if TPC for EC exceeded.	Set TPC once EcoSpec has been calculated, as required.
$MgCl_2$	The 95th percentile of the data must be ≤ 15 mg/L.	The 95^{th} percentile of the data is 12 - 15 mg/L.
$CaCl_2$	The 95th percentile of the data must be ≤ 21 mg/L.	The 95^{th} percentile of the data is 17 - 21 mg/L.
NaCl	Calculate if TPC for EC exceeded.	Set TPC once EcoSpec has been calculated, as required.
$CaSO_4$	The 95th percentile of the data must be ≤ 351 mg/L.	The 95^{th} percentile of the data is 280 - 351 mg/L.
Physical variables		
Electrical Conductivity	The 95th percentile of the data must be ≤ 85 mS/m.	The 95^{th} percentile of the data is 75 - 85 mS/m (**)
pH	The 5th percentile of the data must range from 6.5 to 8.0, and the 95th percentile from 8.0 to 8.8	The 5^{th} percentile of the data is <6.7 and >7.8, and the 95^{th} percentile is <8.2 and >8.6
Temperature	Large changes to temperature regime occur most of the time, with fluctuations of no more than 4°C.	Rely on biotic response data to evaluate whether the TPC for temperature is being reached.
Dissolved oxygen	The 5th percentile of the data must be ≥ 6 mg/L.	The 5^{th} percentile of the data is <6.2 mg/L.
Turbidity	Vary by a small amount from the natural turbidity range. Minor silting of instream habitats is acceptable.	Silting of habitats. Check biotic response for habitat-related changes.
Nutrients		
Total Inorganic Nitrogen (TIN-N)	The 50^{th} percentile of the data must be ≤ 0.25 mg/L.	The 50^{th} percentile of the data must be 0.2 - 0.25 mg/L.
PO_4-P	**PES:** The 50^{th} percentile of the data must be ≤ 0.125 mg/L. **PERC & Post-Dam:** The 50^{th} percentile of the data must be ≤ 0.075 mg/L.	**PES:** The 50^{th} percentile of the data must be 0.06 - 0. 075 mg/L(#). **PERC & Post-Dam:** The 50^{th} percentile of the data must be 0.06 - 0. 075 mg/L.
Response variables		
Chl-*a* phytoplankton	The 50^{th} percentile of the data must be ≤ 20 μg/L(##).	The 50^{th} percentile of the data must be 16 - 20 μg/L(##).
Chl-*a* periphyton	**PES:** The 50^{th} percentile of the data must be ≤ 84 mg/m^2 (##). **PERC & Post-Dam:** The 50^{th} percentile of the data must be ≤ 53 mg/m^2.	**PES:** The 50^{th} percentile of the data must be 67 - 84 mg/m^2 (##). **PERC & Post-Dam:** The 50^{th} percentile of the data must be 42 - 53 mg/m^2.
Toxics		
Copper	The 95^{th} percentile of the data must be ≤ 0.01 mg/L (###).	The 95^{th} percentile of the data is 0.008 - 0.01 mg/L.
Toxics	The 95^{th} percentile of the data must be within the CEV as stated in DWAF (1996a) (####).	An impact is expected if the 95^{th} percentile of the data exceeds the TWQR as stated in DWAF (1996a).

(*) To be generated 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 Na_2SO_4 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.
(**) TPC assigned based on expert judgement due to the small margin between present state and the upper limit of the category.

(#) Although the upper boundary for the relevant phosphate category is 0.125 mg/L, the TPC has been set at 0.075 mg/L as the PES measurements (50th percentile) were 0.026 mg/L (i.e. a C/D category).
(##) Low confidence. EcoSpec and TPC boundaries may need adjusting as data become available.
(###) EcoSpecs and TPCs for PES and scenarios are equivalent as copper exceeds the PES value at present state, i.e. an E category. Even at present state, copper levels should be improved to a D category.
(####) Although category boundaries exist in the Water quality Reserve manual (DWAF, 2008) for a number of toxicants, adherence to the CEV (DWAF, 1996a) is recommended for the present state. Data collection and testing will have to be undertaken to assess the suitability of these objectives.

There is an increase in salinity and nutrients along the reaches of the lower Orange River due to a cumulative effect of irrigation return flows (although limited agriculture in the immediate area) and evaporative losses along the river. The concentration of some metals was reported to be intermittently high at Pella and Vioolsdrift – some evidence of these elevations was seen, although data is very limited. Various incidents suggest toxic events in the river, so the exceedance of TPCs for toxics should be carefully monitored.

Note that due to the paucity of toxics data, no further EcoSpecs or TPCs can be provided with any confidence for the scenarios. Toxics concentrations are expected to drop under the scenarios due to higher flows and dilution in the system. Until more data are available for toxics, assessments of improved state should revert to instream biota as indicators of water quality.

6.2 DIATOMS

Site specific diatom data were available from sample collection during 2008 – 2010 and 2015 across the reach from Vioolsdrift to the Fish River confluence, along with measured *in situ* water quality measurements.

The biological water quality remained relatively stable at a C EC during 2008 and 2009. Water quality deteriorated slightly during 2010 to a C/D EC while the SPI score in 2015 reflected an improvement to a B/C EC. Although elevated at times organic pollution did not seem to be a major problem in this reach, although levels were elevated during 2010. Elevated nutrient levels were a concern as well as salinity. Although still to be verified the presence of *Coscinodiscus devius* indicated that salinity levels increased drastically in 2010 and was of major concern. The 2015 diatom results suggested a decrease in salinity levels from 2010. Valve deformities were only noted in 2015, suggesting that metal toxicity was present at the time of sampling.

The biological water quality of this reach is a C EC. A summary of diatom data collected at EWR O4 is provided in Table 6.4. The EcoSpecs and TPCs for this reach were set at a C Category and provided in Table 6.5.

Table 6.4 EWR O4: Summary of available diatom results

Sample date	SPI	PTV (%)	EC
May 2008	12.3	1.7	C
August 2009	13.0	1.3	C
June 2010	11.4	17.3	C/D
June 2015	14.4	0.5	B/C

Table 6.5 EWR O4: Diatom EcoSpecs and TPCs (C PES)

Metric and associated indicator group/species	Indicator species	EcoSpec	TPC	General comment
SPI score	N/a	12 – 14	11 - 12	The diatom-based water quality for this site should fall within a C Category. If thresholds are exceeded during consecutive low and high flow water quality deterioration should be deemed as serious and impacts should be substantiated with water quality analysis and available data.
PTVs (%)	N/a	<10	>10	PTV scores were generally low indicating that organic pollution levels are generally low. If thresholds are exceeded during consecutive low and high flow this metric should be flagged.
Valve deformities (%)	N/a	<2	>2	A check should be done for valve deformities with every count as this is indicative of metal contamination. If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken to determine the presence of metal toxicity.
Oxygenation				
Achnathidium spp. abundance (% of total count)	Are associated with elevated flows. The genus generally prefers good water quality with high oxygenation rates (Taylor *et al*., 2007b). Species that should be included in count: *A. minutissima, A. biasolettianum, A. pyrenaicum* and *A. rivulare*	>0.5	<0.5	During high/elevated flow this genus must be present and is an important indicator of system recovery. Species should not be absent in more than one high flow sample. If absent, water quality analysis should be undertaken.
Encyonopsis spp. abundance (% of total count)	Cosmopolitan species found in calcareous waters with moderate electrolyte content. Requires an oxygen rich environment (Taylor *et al*., 2007b). Species that should be included in count: *E. minuta, E. microcephala;* and *E. leei* var. *sinensis.*	>0.5	<0.5	This genus should be present in high and low flow samples. They are indicators of good to high oxygenation rates, and are sensitive to water quality deterioration. If absent during three consecutive samples, water quality analysis should be undertaken.
Nutrients				
Cocconeis spp. abundance (% of total count)	The genus *Cocconeis* has a broad ecological range and is found in most running waters except where nutrients are low or acidic conditions prevail (Taylor *et al*., 2007b). This genus is tolerant of moderate organic pollution and also extends into brackish waters. It is abundant on rocks, but is also found on other surfaces such as filamentous algae and macrophytes (Kelly *et al*., 2001). According to Fore and Grafe (2002), *C. placentula* prefer alkaline, eutrophic conditions. Species that should be included in count: *C. placentula, C. pediculus* and *C. placentula* var. *euglypta.*	<5	>5	If thresholds are exceeded during consecutive low and high flow this variable should be flagged.
Nitzschia frustulum (% of total count)	According to Cholnoky (1968) *N. frustulum* is considered a nitrogen heterotroph and Hecky and Kilham (1973) state that it is extremely tolerant of salinity and high alkalinity, and becomes abundant in brackish waters because competition from other diatom species is reduced. It is tolerant of	<3	>3	

Metric and associated indicator group/species	Indicator species	EcoSpec	TPC	General comment
	critical levels of pollution (Taylor *et al.*, 2007b).			
Nitzschia species abundance (% of total count)	Associated with water bodies that have readily available nutrients. Species that should be included in count: *Nitzschia* species with a preference for moderate to high nutrient levels as well as species in girdle view.	<5	>5	
Organics				
Amphora pediculus abundance (% of total count)	A cosmopolitan species found in waters with a moderate electrolyte content and tolerating critical levels of pollution (Taylor *et al.*, 2007b).	<1	>1	If thresholds are exceeded during consecutive low and high flow this metric should be flagged.
Eolimna spp. abundance (% of total count)	Pioneer species ('r-strategists') that colonise bare surfaces and occur in greater abundance with the onset of organic pollution as these species are pioneer species while the community would shift to a dominance of *Sellaphora seminulum* as the community adjusts to the organic pollution levels. Species that should be included in count: *E. minima* and *E. subminuscula*.	<5	>5	
Sellaphora spp. abundance (% of total count)"	Succession occurs in established communities as a result of changes in the physico-chemical environment (Weitzel, 1979). The community would shift to a dominance of *S. seminulum* as the community adjusts to the organic pollution levels and would also be dominant throughout sampling if organic pollution is continual.	<5	>5	
Salinity				
Cyclostephanos spp. abundance (% of total count)	In North America, smaller species of *Cyclostephanos* often dominate the plankton flora during spring and summer in nutrient rich lakes and rivers. Many of the species are tolerant of elevated levels of total dissolved solids and are present in highly calcareous or saline waters (Spaulding and Edlund, 2008). Species that should be included in count: *C. dubius* and *C. invisitatus.*	<5	>5	If thresholds are exceeded during consecutive low and high flow this metric should be flagged.
Stephanodiscus spp. abundance (% of total count)	Occur in waters with elevated electrolyte content. Species that should be included in count: *S. agassizensis*; *S. minutulus* and *S. hantzschii.*	<10	>10	
Pseudostaurosiropsis geocollegarum abundance (% of total count)	Seems to prefer more alkaline waters (pH 7.1 - 8.3), higher conductivity (458 - 1120 µS/cm), and more eutrophic conditions (early eutrophic to dystrophic) (Morales, 2002).	<10	>10	
Turbidity				
Stephanodiscus agassizensis abundance (% of total count)	A planktonic species found in eutrophic rivers and lakes with an elevated electrolyte concentration and turbidity (Taylor *et al.*, 2007b)	<2	>2	If thresholds are exceeded during consecutive low and high flow this metric should be flagged.

6.3 RIPARIAN VEGETATION

The EcoSpecs and TPCs for riparian vegetation (Table 6.6) are provided below.

Table 6.6 EWR O4: Riparian vegetation EcoSpecs and TPCs (PES C; PERC and Post-Dam Sc: B/C)

Component	EcoSpec: PES (C)	TPC: PES (C)	EcoSpec: PERC and Post Dam (B/C)	TPC: PERC and Post Dam (B/C)
Riparian zone				
Alien Invasion (perennial aliens)	Maintain alien species cover below 20%.	An increase in alien species cover above 20%.	Maintain alien species cover below 15%.	An increase in alien species cover above 15%.
Marginal Zone				
Terrestrialisation	Maintain an absence of terrestrial species.	An occurrence of terrestrial species.	Maintain an absence of terrestrial species.	An occurrence of terrestrial species.
Indigenous Riparian Woody Cover	Maintain indigenous riparian woody cover between 1 and 80%.	An increase in riparian woody species cover above 80% OR an absence of riparian woody species.	Maintain indigenous riparian woody cover between 1 and 70%.	An increase in riparian woody species cover above 70% OR an absence of riparian woody species.
P. australis (reed) cover	Maintain reed cover below 50%.	An increase in reed cover above 50%.	Maintain reed cover below 45%.	An increase in reed cover above 45%.
Lower Zone				
Terrestrialisation	Maintain cover of terrestrial species at 10% or less.	An increase above 10% of terrestrial species cover.	Maintain cover of terrestrial species at 5% or less.	An increase above 5% of terrestrial species cover.
Indigenous Riparian Woody Cover	Maintain indigenous riparian woody cover below 60%.	An increase in riparian woody species cover above 60%.	Maintain indigenous riparian woody cover below 55%.	An increase in riparian woody species cover above 55%.
P. australis (reed) cover	Maintain reed cover below 50%.	An increase in reed cover above 50%.	Maintain reed cover below 45%.	An increase in reed cover above 45%.
Upper Zone				
Terrestrialisation	Maintain cover of terrestrial species at 30% or less.	An increase above 30% of terrestrial species cover.	Maintain cover of terrestrial species at 20% or less.	An increase above 20% of terrestrial species cover.
Indigenous Riparian Woody Cover	Maintain indigenous riparian woody cover between 5 and 90%.	An increase in riparian woody species cover above 90% OR a decrease below 5%.	Maintain indigenous riparian woody cover between 10 and 80%.	An increase in riparian woody species cover above 80% OR a decrease below 10%.
MCB				
Terrestrialisation	Maintain cover of terrestrial species at 30% or less.	An increase above 30% of terrestrial species cover.	Maintain cover of terrestrial species at 30% or less.	An increase above 30% of terrestrial species cover.
Indigenous Riparian Woody Cover	Maintain indigenous riparian woody cover above 10%.	A decrease in riparian woody cover below 10%.	Maintain indigenous riparian woody cover above 20%.	A decrease in riparian woody cover below 20%.

6.4 FISH

EcoSpecs and TPCs for FRAI data are provided in Table 6.7 for a PES of a C which is the same for PERC and an EcoStatus of B/C for Post-Dam. The spatial FROC of EWR O4 is provided in

Table 6.8 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

Table 6.7 EWR O4: Fish EcoSpecs and TPCs (PES & PERC: C; Post-Dam: B/C (REC))

Indicator	PES & PERC: C				
	EWR Site			Reach	
	EcoSpecs	TPC (Biotic)	TPC (Habitat)	Indicator Spp.	TPC (Biotic)
Rank 1. Species richness					
All Indigenous Spp.	**Ten (10)** of the expected (under reference conditions) 12 indigenous fish species were sampled during the baseline (EWR) survey.	**Less than 8** fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity - depth categories and cover features.	All indigenous species	Baseline (PES) FRAI score of 65% (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 62.02% (C/D).
Rank 2. Relative abundance					
N/A	During baseline (EWR) surveys fish were sampled at **3.5** ind/min using a SAMUS electrofisher (wading and from boat). Overall relative abundance was high.	Relative abundance of **less than 2.5** ind/min sampled at the site (during same season as baseline data) when habitat can be sampled efficiently and using comparable method.	N/A	N/A	N/A
Rank 8. Any alien/introduced fish species					
Any alien/ introduced spp.	One indigenous introduced fish species (OMOS) and one alien (CCAR) was sampled at the site during the baseline EWR survey. OMOS was recorded at 0.2 ind/min, while CCAR was scarce at 0.02 ind/min.	Present of any additional alien/introduced species at site, or OMOS present at relative abundance > 0.25 ind/min and CCAR >0.1 ind/min.	N/A	Any alien/ introduced spp.	Increase in the number of alien species (>2 species in reach) OR presence of any alien species other than CCAR and OMOS.
Rank 3: FD habitats, substrate, flow dependant spp. (flow alteration) SD habitats					
BAEN LCAP	The two indicator species of this metric group, BAEN and LCAP, were sampled at the site during the baseline EWR surveys. BAEN was present at 0.2 ind/min while LCAP was present at 1 ind/min.	BAEN **and/or** LCAP absent during any survey **OR** present at relative abundance of <0.1 ind/min for BAEN or <0.7 ind/min for LCAP.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates. Increased sedimentation of	LCAP BAEN	Any decreased FROC in reach of BAEN and LCAP (refer to sheet 5 - FROC, column F: Table 2).

Indicator	PES & PERC: C				
	EWR Site			Reach	
	EcoSpecs	TPC (Biotic)	TPC (Habitat)	Indicator Spp.	TPC (Biotic)
			riffle/rapid substrates, excessive algal growth on substrates.		
Rank 3: FS habitats					
BAEN BKIM	The two indicator species of this metric group, BAEN and BKIM were sampled at the site during the baseline EWR surveys. BAEN was present at 0.2 ind/min while BKIM was very scarce at 0.01 ind/min.	BAEN absent during any survey **OR** BKIM absent during two consecutive surveys (>50% of time) AND/OR BAEN present at relative abundance of <0.1 ind/min.	Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows).	BAEN BKIM	Any decreased FROC in reach of BAEN and BKIM (refer to sheet 5 - FROC, column F: Table 2)
Rank 3: Water quality intolerance					
BKIM LCAP	The two indicator species of this metric group, BKIM and LCAP, were sampled at the site during the baseline EWR surveys. BKIM was very scarce at 0.01 ind/min while LCAP was abundant at 1 ind/min.	LCAP absent during any survey, BKIM absent during two consecutive surveys (>50% of time) OR present at relative abundance of <0.7 ind/min for LCAP.	Decreased water quality.	BKIM LCAP	Any decreased FROC in reach of BKIM and LCAP (refer to sheet 5 - FROC, column F: Table 2).
Rank 4: Water column					
MBRE BAEN	The two indicator species of this metric BAEN and MBRE were sampled at the site during the baseline EWR surveys. BAEN was present at 0.2 ind/min while MBRE was abundant at 1 ind/min.	BAEN **and/or** MBRE absent during any survey **OR** present at relative abundance of <0.1 ind/min for BAEN or <0.7 ind/min for MBRE.	Reduction in suitability of water column (i.e. increased sedimentation of pools).	MBRE BAEN	Any decreased FROC in reach of MBRE and BAEN (refer to sheet 5 - FROC, column F: Table 2).
Rank 6: SS habitats , overhanging vegetation					
PPHI TSPA	The two indicator species of this metric PPHI and TSPA were sampled at the site during the baseline EWR surveys. PPHI was present at 0.02 ind/min while TSPA was very scarce at 0.24 ind/min.	PPHI **and/or** TSPA absent during any survey **OR** present at relative abundance of <0.01 ind/min for PPHI or <0.15 ind/min for TSPA.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats). Significant change in overhanging vegetation habitats.	PPH TSPA	Any decreased FROC in reach of PPHI and TSPA (refer to sheet 5 - FROC, column F: Table 2).
Rank 7: Undercut banks					
PPHI	With ASCL not sampled at the EWR site during the baseline survey, PPHI is the only indicator species of this	PPHI absent during any survey **OR** present at relative abundance of <0.01 ind/min for PPHI.	Significant change in undercut bank habitats (e.g. bank erosion, reduced flows).	PPHI ASCL	Any decreased FROC in reach of PPHI and ASCL (refer to sheet 5 - FROC,

Indicator	PES & PERC: C				
	EWR Site			Reach	
	EcoSpecs	TPC (Biotic)	TPC (Habitat)	Indicator Spp.	TPC (Biotic)
	metric. PPHI was present at 0.02 ind/min.				column F: Table 2).
Rank 8: Instream vegetation					
BPAU TSPA	The two indicator species of this metric BPAU and TSPA were sampled at the site during the baseline EWR surveys. BPAU was present at 0.02 ind/min while TSPA was very scarce at 0.24 ind/min.	BPAU **and/or** TSPA absent during any survey **OR** present at relative abundance of <0.01 ind/min for BPAU or <0.15 ind/min for TSPA.	Significant change in overhanging vegetation habitats.	TSPA BPAU	Any decreased FROC in reach of TSPA and BPAU (refer to sheet 5 - FROC, column F: Table 2).

Table 6.8 EWR O4: Spatial FROC under reference, PES, PERC, Post-Dam and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		Reference (A)	PES & PERC: C EC		Post-Dam: B/C EC (REC)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/ derived FROC
Indigenous species					
BPAU*	*Barbus paludinosus* (Peters, 1852)	4	3	2	3.5
BTRI*	*Barbus trimaculatus* (Peters, 1852)	4	3	2	3.5
CGAR*	*Clarias gariepinus* (Burchell, 1822)	4	3.5	2.5	3.5
LCAP*	*Labeo capensis* (Smith, 1841)	5	4	3	4.5
LUMB	*Labeo umbratus* (Smith, 1841)	1	0.5	0	0.5
MBRE*	*Mesobola brevianalis* (Boulenger, 1908)	4	3.5	2.5	3.5
PPHI*	*Pseudocrenilabrus philander* (Weber, 1897)	4	3	2	3.5
TSPA*	*Tilapia sparrmanii* (Smith, 1840)	4	3	2	3.5
Introduced species					
CCAR*	*Cyprinus carpio* (Linnaeus, 1758)	0	2	4	1
OMOS*	*Oreochromis mossambicus* (Peters, 1852)	0	0	0	0

* Sampled at EWR site during baseline survey (June 2010).

6.5 MACROINVERTEBRATES

6.5.1 SASS data

Available SASS5 data collected at or near Site EWR O4 are summarised in Table 6.9.

Table 6.9 EWR O4: Available SASS 5 data

Site	Date	SASS Score	ASPT	No. of Taxa	Reference
D8ORAN-SENDU	13-Jan-2004	146	5.8	25	Rob Palmer (River Health Database)
D8ORAN-SENDD	14-Jan-2004	98	5.4	18	Rob Palmer (River Health Database)
D8ORAN-PELLA	14-Oct-2004	34	5.7	6	Ramogale Sekwele (River Health Database)
D8ORAN-RICHT	18-Apr-2005	33	4.7	7	Ramogale Sekwele (River Health Database)
D8ORAN-PELLA	19-Apr-2005	38	4.8	8	Ramogale Sekwele (River Health Database)
D8ORAN-GOODH	19-Apr-2005	28	4	7	Ramogale Sekwele (River Health Database)
D8ORAN-VIOOL	19-Apr-2005	44	4.9	9	Ramogale Sekwele (River Health Database)
D8ORAN-RICHT	21-Nov-2005	115	5.5	21	Ramogale Sekwele (River Health Database)
D8ORAN-GOODH	22-Nov-2005	63	5.7	11	Ramogale Sekwele (River Health Database)
D8ORAN-VIOOL	22-Nov-2005	62	4.8	13	Ramogale Sekwele (River Health Database)
EWR O4	26-May-2010	96	6.0	16	This study

6.5.2 Indicator taxa

Perlidae, Baetidae (>2 spp.), Tricorythidae, Atyidae, Elmidae, and Hydropsychidae (2 spp.) were selected as monitoring indicators for EWR O4. Table 6.10 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 6.10 EWR O4: Habitat preference of macroinvertebrate 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	10				
Moderate (SASS 7 - 10)			9	8	8	
Low (SASS 4 - 6)						6

6.5.3 EcoSpecs and TPCs

The EcoSpecs and TPCs for macroinvertebrates, based on an EcoStatus of a C for the PES and B/C for PERC and Post-Dam, are provided in Table 6.11.

Table 6.11 EWR O4: Macroinvertebrate EcoSpecs and TPCs (PES: C; PERC and Post-Dam Sc: B/C (REC))

EcoSpecs	TPCs
SASS5 Score between 143 and 161.	SASS5 Score < 150
ASPT between 5.9 and 6.3.	ASPT < 6.1.
MIRAI Score between 60% and 79%.	MIRAI Score < 63%.
At least 50% indicator taxa present.	Three or more Indicator Taxa absent.
Indicator Taxa	
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 two or more consecutive surveys.
Elmidae present.	Elmidae absent on two or more consecutive surveys.
Hydropsychidae present.	Hydropsychidae absent on two or more consecutive surveys.

7 EWR O5 (SENDELINGSDRIFT): ECOSPECS AND TPCs

A summary of the site EcoClassification results are provided below (DWS, 2016b).

Table 7.1 EWR O5: EcoClassification results

EWR O5 (SENDLINGSDRIFT)

EIS: HIGH
Highest scoring metrics are rare and endangered instream and riparian species. Unique instream and riparian species. Important migration corridor for various species. The site is situated in the /Ai-/Ais–Richtersveld Transfrontier Park.

PES: B/C
Decreased small and moderate flood frequency. Agricultural return flows and mining activities – water quality problems. Higher low flows than natural in the dry season, drought and dry periods. Decreased low flows at other times. The presence of alien fish and vegetation species. Barrier effect of dams.

REC: B
Increased (from present) wet season base flows. Reinstate dry season droughts.

Driver Components	PES	REC
IHI HYDROLOGY	C	C
WATER QUALITY	C	C
GEOMORPHOLOGY	B/C	B
INSTREAM IHI	C	
RIPARIAN IHI	C	
Response Components	**PES**	**REC**
FISH	B/C	B
MACRO INVERTEBRATES	B/C	B
INSTREAM	B/C	B
RIPARIAN VEGETATION	B/C	B
RIVERINE FAUNA	B	B
ECOSTATUS	B/C	B
EIS	HIGH	

The PERC for the components for which EcoSpecs are set are provided in Table 7.2. Note that the estimated changes for the EcoSpecs associated with a post dam development scenario are also provided.

Table 7.2 EWR O5: PERC

Driver components	PES	REC	Pre-Dam recommendation PERC (Sc A2; A3)	Post-Dam recommendation D Scenarios*
Physico chemical	C	C	B/C	B/C
Fish	B/C	B	B	B
Invertebrates	B/C	B/C	B/C	B/C
Riparian vegetation	B/C	B	B	B
EcoStatus	B/C	B	B	B

* Further investigations are necessary on dam sizes to finalise the post-dam scenario recommendations. However, as the differences between the D and C Scenarios are relatively small, an indication of EcoSpecs and TPCs associated with the D scenarios (small dam) has been provided. This will be updated during the Classification study that will folllow.

EcoSpecs and TPCs for EWR O5 are provided for the different components in Section 7.1 to 7.5.

7.1 WATER QUALITY

The EcoSpecs and TPCs for water quality (Table 7.3) are provided below.

Table 7.3 EWR O5: Water quality EcoSpecs and TPCs (PES and PERC: C; Post-Dam Sc: C)

Water quality metrics	EcoSpecs	TPC
Inorganic salts(*)		
$MgSO_4$	**PES, scenarios:** Calculate if TPC for EC exceeded.	**PES, scenarios:** Set TPC once EcoSpec has been calculated, as required.
Na_2SO_4	**PES, scenarios:** Calculate if TPC for EC exceeded.	**PES, scenarios:** Set TPC once EcoSpec has been calculated, as required.
$MgCl_2$	The 95th percentile of the data must be ≤ 15 mg/L.	The 95th percentile of the data is 12 - 15 mg/L.
$CaCl_2$	The 95th percentile of the data must be ≤ 21 mg/L.	The 95th percentile of the data is 17 - 21 mg/L.
NaCl	**PES, scenarios:** Calculate if TPC for EC exceeded.	**PES, scenarios:** Set TPC once EcoSpec has been calculated, as required.
$CaSO_4$	The 95th percentile of the data must be ≤ 351 mg/L.	The 95th percentile of the data is 280 - 351 mg/L.
Physical variables		
Electrical Conductivity (**)	**PES:** The 95th percentile of the data must be ≤ 85 mS/m. **Post-Dam:** The 95th percentile of the data must be ≤ 55 mS/m.	**PES:** The 95th percentile of the data is 75 - 85 mS/m. **Post-Dam:** The 95th percentile of the data is 44 - 55 mS/m.
pH	The 5th percentile of the data must range from 6.5 to 8.0, and the 95th percentile from 8.8 to 9.2	The 5th percentile of the data is < 6.7 and > 7.8, and the 95th percentile is < 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	**PES:** The 5th percentile of the data must be ≥ 7 mg/L. **Post-Dam:** The 5th percentile of the data must be ≥ 7.5 mg/L.	**PES:** The 5th percentile of the data must be 7.2 - 7.0 mg/L. **Post-Dam:** The 5th percentile of the data must be 7.7 – 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.	Silting of habitats. Check biotic response for habitat - related changes.
Nutrients		
Total Inorganic Nitrogen (TIN-N)	The 50th percentile of the data must be ≤ 0.25 mg/L.	The 50th percentile of the data must be 0.2 – 0.25 mg/L.
PO_4-P	**PES:** The 50th percentile of the data must be ≤ 0.025 mg/L. **Post-Dam:** The 50th percentile of the data must be ≤ 0.02 mg/L.	**PES:** The 50th percentile of the data must be 0.02 – 0. 025 mg/L. **Post-Dam:** The 50th percentile of the data must be 0.016 – 0.02 mg/L.
Response variables		
Chl-*a* phytoplankton(#)	The 50th percentile of the data must be ≤ 20 mg/L.	The 50th percentile of the data must be 16 – 20 µg/L.
Chl-*a* periphyton(#)	**PES:** The 50th percentile of the data must be ≤ 21 mg/m^2. **Post-Dam:** The 50th percentile of the data must be ≤ 12 mg/m^2.	**PES:** The 50th percentile of the data must be 17 – 21 mg/m^2. **Post-Dam:** The 50th percentile of the data must be 10 – 12 mg/m^2.
Toxics		
Copper (mg/L)	The 95th percentile of the data must be ≤ 0.01 mg/L(##)	The 95th percentile of the data is 0.008 – 0.01 mg/L.
Toxics (###)	The 95th percentile of the data must be	An impact is expected if the 95th percentile

Water quality metrics	EcoSpecs	TPC
	within the CEV as stated in DWAF (1996a).	of the data exceeds the TWQR as stated in DWAF (1996a).

(*). To be generated 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.
(**) TPC assigned based on expert judgement due to the small margin between present state and the upper limit of the category.
(#) Low confidence. EcoSpec and TPC boundaries may need adjusting as data become available.
(##) EcoSpecs and TPCs for PES and scenarios are equivalent as copper exceeds the PES value at present state, i.e. an E Category. Even at present state, copper levels should be improved to a D Category.
(###) Although category boundaries exist in the Water quality Reserve manual (DWAF, 2008) for a number of toxicants, adherence to the CEV (DWAF, 1996a) is recommended for the present state. Data collection and testing will need to be undertaken to assess the suitability of these objectives.

Main water quality issues in this section are elevated nutrient loads, elevations in salts and some elevated metals, related to irrigation return flows from upstream farming and mining activities in the area. All issues are exacerbated by fluctuating flows.

Note that due to the paucity of toxics data, no further EcoSpecs or TPCs can be provided with any confidence for the scenarios. Toxics concentrations are expected to drop slightly under the scenarios due to higher flows and dilution in the system. Until more data are available for toxics, assessments of improved state should revert to instream biota as indicators of water quality.

7.2 DIATOMS

Site specific diatom data were available from sample collection during 2008 – 2010 and 2013 at Sendelingsdrift, along with measured *in situ* water quality measurements.

The biological water quality remained relatively stable at a C/D EC during 2008, 2009 and 2012. Water quality improved during 2010 to a B/C EC. Organic pollution levels were elevated for most of the times while nutrient and salinity levels fluctuated. Species with a preference for moderate water quality with elevated salinity levels were generally prolific.

The biological water quality of this reach is a C/D EC. A summary of diatom data collected at EWR O5 is provided in Table 7.4. The EcoSpecs and TPCs for this reach were set at a C/D Category and provided in Table 7.5.

Table 7.4 EWR O5: Summary of available diatom results

Sample date	SPI	PTV (%)	EC
June 2008	10.1	18.2	C/D
August 2009	10.1	13.8	C/D
June 2010	14.4	1.3	B/C
June 2012	11.4	12.8	C/D

Table 7.5 EWR O5: Diatom EcoSpecs and TPCs (C PES)

Metric and associated indicator group/species	Indicator species	EcoSpec	TPC	General comment
SPI score	N/a	10 – 12	8 - 10	The diatom-based water quality for this site should fall within a C/D Category. If thresholds are exceeded during consecutives low and high flow water quality deterioration should be deemed as serious and impacts should be substantiated with water quality analysis and available data.
PTVs (%)	N/a	<15	>15	PTV scores were generally moderate indicating that organic pollution levels are generally moderate. If thresholds are exceeded during consecutives low and high flow this metric should be flagged.
Valve deformities (%)	N/a	<2	>2	A check should be done for valve deformities with every count as this is indicative of metal contamination. If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken to determine the presence of metal toxicity.
Oxygenation				
Achnathidium spp. abundance (% of total count)	Are associated with elevated flows. The genus generally prefers good water quality with high oxygenation rates (Taylor *et al.*, 2007b). Species that should be included in count: *. minutissima, A. biasolettianum, A. pyrenaicum* and *A. rivulare*	>0.5	<0.5	During high/elevated flow this genus must be present and is an important indicator of system recovery. Species should not be absent in more than one high flow sample. If absent, water quality analysis should be undertaken.
Encyonopsis spp. abundance (% of total count)	Cosmopolitan species found in calcareous waters with a moderate electrolyte content. Requires an oxygen rich environment (Taylor *et al.*, 2007b). Species that should be included in count: *E. minuta, E. microcephala,* and *E. leei* var. *sinensis.*	>0.5	<0.5	This genus should be present in high and low flow samples. They are indicators of good to high oxygenation rates, and are sensitive to water quality deterioration. If absent during three consecutive samples, water quality analysis should be undertaken.
Nutrients				
Nitzschia frustulum abundance (% of total count)	According to Cholnoky (1968) *N. frustulum* is considered a nitrogen heterotroph and Hecky and Kilham (1973) state that it is extremely tolerant of salinity and high alkalinity, and becomes abundant in brackish waters because competition from other diatom species is reduced. It is tolerant of critical levels of pollution (Taylor *et al.*, 2007b).	<10	>10	If thresholds are exceeded during consecutive low and high flow this variable should be flagged.
Nitzschia species abundance (% of total count)	Associated with water bodies that have readily available nutrients. Species that should be included in count: *Nitzschia* species with a preference for moderate to high nutrient levels as well as species in girdle view.	<7	>7	

Metric and associated indicator group/species	Indicator species	EcoSpec	TPC	General comment
Organics				
Eolimna spp. abundance (% of total count)	*Eolimna* species: Pioneer species ('r-strategists') that colonise bare surfaces and occur in greater abundance with the onset of organic pollution as these species are pioneer species while the community would shift to a dominance of *Sellaphora seminulum* as the community adjusts to the organic pollution levels. Species that should be included in count: *E. minima* and *E. subminuscula*.	<7	>7	If thresholds are exceeded during consecutive low and high flow this variable should be flagged.
Sellaphora spp. abundance (% of total count)"	*Sellaphora seminulum*: Succession occurs in established communities as a result of changes in the physico-chemical environment (Weitzel, 1979). the community would shift to a dominance of *S. seminulum* as the community adjusts to the organic pollution levels and would also be dominant throughout sampling if organic pollution is continual.	<7	>7	
Nitzschia palea abundance (% of total count)"	*Nitzschia palea*: A cosmopolitan and very commonly occurring species found in eutrophic and very heavily polluted to extremely polluted waters with moderate to high electrolytecontent (Taylor et al., 2007b).	<10	>10	
Salinity				
Cyclostephanos spp. abundance (% of total count)	In North America, smaller species of *Cyclostephanos* often dominate the plankton flora during spring and summer in nutrient rich lakes and rivers. Many of the species are tolerant of elevated levels of total dissolved solids and are present in highly calcareous or saline waters (Spaulding and Edlund, 2008). Species that should be included in count: *C. dubius* and *C. invisitatus.*	<10	>10	If thresholds are exceeded during consecutive low and high flow this metric should be flagged.
Stephanodiscus spp. abundance (% of total count)	*Stephanodiscus* species: Occur in waters with elevated electrolyte content. Species that should be included in count: *S. agassizensis*; *S. minutulus* and *S. hantzschii.*	<10	>10	
Pseudostaurosiropsis geocollegarum abundance (% of total count)	*P. geocollegarum*: Seems to prefer more alkaline waters (pH 7.1 - 8.3), higher conductivity (458 - 1120 µS/cm), and more eutrophic conditions (early eutrophic to dystrophic) (Morales, 2002).	<20	>20	
Turbidity				
Stephanodiscus agassizensis abundance (% of total count)	A planktonic species found in eutrophic rivers and lakes with an elevated electrolyte concentration and turbidity (Taylor *et al.*, 2007b)	<4	>4	If thresholds are exceeded during consecutive low and high flow this metric should be flagged.

7.3 RIPARIAN VEGETATION

The EcoSpecs and TPCs for riparian vegetation (Table 7.6) are based on the PES of a B/C and PERC and post-dam of a B.

Table 7.6 EWR O5: Riparian vegetation EcoSpecs and TPCs (PES and PERC: B/C: Post-Dam Sc: B)

Assessed Component	EcoSpec: PES & PERC (B/C)	TPC: PES & PERC (B/C)	EcoSpec: Post-Dam (B/C)	TPC: Post-Dam (B/C)
Riparian zone excluding MCB				
Salix mucronata population cover	Maintain population cover between 5% and 50%.	A decrease in population cover below 5% OR an increase in population cover above 50%.	Maintain population cover between 5% and 50%.	A decrease in population cover below 5% OR an increase in population cover above 50%.
Marginal Zone				
Phragmites (reed) cover	Maintain reed cover below 50%.	An increase in reed cover above 50%.	Maintain reed cover below 40%.	An increase in reed cover above 40%.
Sedge cover	Maintain sedge above 5%.	A decrease in sedge cover below 5%.	Maintain sedge above 5%.	A decrease in sedge cover below 5%.
Lower Zone				
Phragmites (reed) cover	Maintain reed cover below 50%.	An increase in reed cover above 50%.	Maintain reed cover below 40%.	An increase in reed cover above 40%.
Sedge cover	Maintain sedge above 5%.	A decrease in sedge cover below 5%.	Maintain sedge above 5%.	A decrease in sedge cover below 5%.
MCB				
Perennial alien species invasion	Maintain alien perennial species below 15%.	An increase in alien perennial species cover above 15%.	Maintain alien perennial species below 10%.	An increase in alien perennial species cover above 10%.
Indigenous Riparian Woody Cover	Maintain riparian woody species cover above 60%.	A decrease in riparian woody cover on the MCB below 60%.	Maintain riparian woody species cover above 70%.	A decrease in riparian woody cover on the MCB below 70%.
Indigenous Riparian Woody Structure	Maintain woody structure as closed woodland (Edwards, 1983).	Opening up of the closed woodland.	Maintain woody structure as closed woodland (Edwards, 1983).	Opening up of the closed woodland.
Euclea pseudebenus population structure	Maintain population structure with a ratio of 80% adult, 10% sub-adult and 10% juvenile.	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%.	Maintain population structure with a ratio of 80% adult, 10% sub-adult and 10% juvenile.	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%.
Searsia pendulina population cover	Maintain at least 40% of total woody cover.	Decrease in *S. pendulina* cover below 40% of total woody cover on MCB.	Maintain at least 40% of total woody cover.	Decrease in *S. pendulina* cover below 40% of total woody cover on MCB.
Floodplain				

Assessed Component	EcoSpec: PES & PERC (B/C)	TPC: PES & PERC (B/C)	EcoSpec: Post-Dam (B/C)	TPC: Post-Dam (B/C)
Perennial alien species invasion	Maintain alien perennial species below 15%.	An increase in alien perennial species cover above 15%.	Maintain alien perennial species below 10%.	An increase in alien perennial species cover above 10%.
Indigenous Riparian Woody Cover	Maintain riparian woody species cover above 40%.	A decrease in riparian woody cover on the floodplain below 40%.	Maintain riparian woody species cover above 50%.	A decrease in riparian woody cover on the floodplain below 50%.
Indigenous Riparian Woody Structure	Maintain woody structure as open woodland.	Opening up of the open woodland to sparse.	Maintain woody structure as open woodland.	Opening up of the open woodland to sparse.
Euclea pseudebenus population structure	Maintain population structure with a ratio of 80% adult, 10% sub-adult and 10% juvenile.	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%	Maintain population structure with a ratio of 80% adult, 10% sub-adult and 10% juvenile.	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%
All zones				
Prosopis species invasion	Keep specific plant species cover to less than 5%.	An increase in specific plant species cover above 5%.	Keep specific plant species cover to less than 5%.	An increase in specific plant species cover above 5%.
Nicotiana glauca invasion	Keep specific plant species cover to less than 5%.	An increase in specific plant species cover above 5%	Keep specific plant species cover to less than 5%.	An increase in specific plant species cover above 5%.

7.4 FISH

EcoSpecs and TPCs for FRAI data are provided in Table 7.7. The spatial FROC of EWR O5 is provided in Table 7.8 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

Table 7.7 EWR O5: Fish EcoSpecs and TPCs (PES and PERC: B/C; Post-Dam Sc: B (REC))

Indicator	PES & PERC: B/C				
	EWR Site			Reach	
	EcoSpecs	TPC (Biotic)	TPC (Habitat)	Indicator Spp.	TPC (Biotic)
Rank 1. Species richness					
All Indigenous Spp.	**Eleven (11)** of the expected (under reference conditions). Twelve indigenous fish species were sampled during the baseline (EWR) survey.	**Less than ten (10)** fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity - depth categories and cover features.	All indigenous species	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 EC).
Rank 2. Relative abundance					
All Indigenous Spp.	During baseline (EWR) surveys fish were sampled at 1.8 ind/min using a SAMUS electrofisher (wading). Overall relative abundance was high.	Relative abundance of less than one ind/min sampled at the site (during same season as baseline data) when habitat can be sampled efficiently and using comparable method.	N/A	N/A	N/A
Rank 3. FD and SD habitats, substrate, Flow dependant spp. (flow alteration)					
BAEN LCAP	The two indicator species of this metric group, BAEN and LCAP, were sampled at the site during the baseline EWR surveys. BAEN was present at 0.5 ind/min while LCAP was present at 0.9 ind/min.	BAEN **and/or** LCAP absent during any survey **or** present at relative abundance of <0.2 ind/min for BAEN or <0.5 ind/min for LCAP.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates.	BAEN LCAP	Any decreased FROC in reach of BAEN and LCAP (refer to sheet 5 - FROC, column F: Table 2).
Rank 3: FS habitats					
BAEN BKIM	The two indicator species of this metric group, BAEN and BKIM were sampled at the site during the baseline EWR surveys. BAEN was present at 0.5 ind/min while BKIM was	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 ind/min.	Reduced suitability (abundance and quality) of Fast Shallow habitats (i.e. decreased flows, increased zero flows).	BAEN BKIM	Any decreased FROC in reach of BAEN and BKIM (refer to sheet 5 - FROC, column F: Table 2).

<table>
<tr><th rowspan="3">Indicator</th><th colspan="5">PES & PERC: B/C</th></tr>
<tr><th colspan="3">EWR Site</th><th colspan="2">Reach</th></tr>
<tr><th>EcoSpecs</th><th>TPC (Biotic)</th><th>TPC (Habitat)</th><th>Indicator Spp.</th><th>TPC (Biotic)</th></tr>
<tr><td></td><td>very scarce at 0,01 ind/min.</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Rank 3: Water quality intolerance</td></tr>
<tr><td>BKIM
LCAP</td><td>The two indicator species of this metric group, BKIM and LCAP, were sampled at the site during the baseline EWR surveys. BKIM was very scarce at 0.01 ind/min while LCAP was abundant at 0.9 ind/min.</td><td>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 ind/min for LCAP may indicate on deterioration.</td><td>Decreased water quality.</td><td>BKIM
LCAP</td><td>Any decreased FROC in reach of BKIM and LCAP (refer to sheet 5 - FROC, column F: Table 2).</td></tr>
<tr><td colspan="6">Rank 4: Water column</td></tr>
<tr><td>BAEN
MBRE</td><td>The two indicator species of this metric, BAEN and MBRE were sampled at the site during the baseline EWR surveys. BAEN was present at 0.2 ind/min while MBRE was sampled at 0.14 ind/min.</td><td>BAEN and/or MBRE absent during any survey or present at relative abundance of <0.2 ind/min for BAEN or <0.05 ind/min for MBRE.</td><td>Reduction in suitability of water column (i.e. increased sedimentation of pools).</td><td>BAEN
MBRE</td><td>Any decreased FROC in reach of BAEN and MBRE (refer to sheet 5 - FROC, column F: Table 2).</td></tr>
<tr><td colspan="6">Rank 5: Overhanging vegetation</td></tr>
<tr><td>PPHI
BPAU</td><td>The two indicator species of this metric, PPHI and BPAU were sampled at the site during the baseline EWR surveys. PPHI was present at 0.01 ind/min while BPAU was sampled 0.09 ind/min.</td><td>BPAU absent during any survey or PPHI absent during two consecutive surveys or BPAU present at relative abundance of <0.04 ind/min.</td><td>Significant change in overhanging vegetation habitats.</td><td>PPHI
BPAU</td><td>Any decreased FROC in reach of PPHI and BPAU (refer to sheet 5 - FROC, column F: Table 2).</td></tr>
<tr><td colspan="6">Rank 5: Instream vegetation</td></tr>
<tr><td>BPAU
TSPA</td><td>The two indicator species of this metric, BPAU and TSPA were sampled at the site during the baseline EWR surveys. BPAU was present at</td><td>BPAU absent during any survey and/or TSPA absent during two consecutive surveys and/or BPAU present at relative abundance of <0,04 ind/min.</td><td>Significant change in overhanging vegetation habitats (overgrazing, flow modification).</td><td>BPAU
TSPA</td><td>Any decreased FROC in reach of BPAU and TSPA (refer to sheet 5 - FROC, column F: Table 2).</td></tr>
</table>

Indicator	PES & PERC: B/C				
	EWR Site			Reach	
	EcoSpecs	TPC (Biotic)	TPC (Habitat)	Indicator Spp.	TPC (Biotic)
	0.09 ind/min while TSPA was very scarce at 0,01 ind/min.				
Rank 6: SS habitats					
PPHI MBRE	The two indicator species of this metric, PPHI and MBRE were sampled at the site during the baseline EWR surveys. PPHI was present at 0.01 ind/min while MBRE was sampled 0.14 ind/min.	PPHI absent during two consecutive surveys **and/or** MBRE absent during any survey **or** MBRE present at relative abundance of <0.01 ind/min.	Significant change in Slow Shallow habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).	PPHI MBRE	Any decreased FROC in reach of PPHI and MBRE (refer to sheet 5 - FROC, column F: Table 2).
Rank 7: Undercut Banks					
PPHI ASCL	The two indicator species of this metric, PPHI and ASCL were sampled at the site during the baseline EWR surveys. Both species were scarce, being present at 0.01 ind/min.	PPHI or ASCL absent during two consecutive surveys.	Significant change in undercut bank habitats (e.g. bank erosion, reduced flows).	PPHI ASCL	Any decreased FROC in reach of PPHI and ASCL (refer to sheet 5 - FROC, column F: Table 2).
Rank 8: Alien fish species					
Any alien/ introduced species	One indigenous introduced fish species (OMOS) was, sampled at the site during the baseline EWR survey. OMOS was recorded at 0.04 ind/min.	Presence of any additional alien/introduced species at site, **or** OMOS present at relative abundance > 0.1 ind/min.	N/a	Any alien/ introduced species	

Table 7.8 EWR O5: Spatial FROC under reference, PES and PERC conditions, Post-Dam Sc (=REC) and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		Reference (A)	PES & PERC: B/C EC		Post Dam: B (REC)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/ derived FROC
Indigenous species					
ASCL*	*Barbus paludinosus* (Peters, 1852)	1	1	0	1
BAEN*	*Labeobarbus aeneus* (Burchell, 1822)	5	5	4	5
BHOS*	*Barbus hospes* (Barnard, 1938)	4	4	0	4
BKIM*	*Labeobarbus kimberleyensis* (Gilchrist & Thompson, 1913)	3	2	1	2
BPAU*	*Barbus paludinosus* (Peters, 1852)	4	3.5	2.5	3.5
BTRI*	*Barbus trimaculatus* (Peters, 1852)	4	2	1	3
CGAR*	*Clarias gariepinus* (Burchell, 1822)	4	4	3	4
LCAP*	*Labeo capensis* (Smith, 1841)	5	5	4	5
LUMB*	*Labeo umbratus* (Smith, 1841)	1	0.5	0	0.5
MBRE*	*Mesobola brevianalis* (Boulenger, 1908)	4	4	3	4
PPHI*	*Pseudocrenilabrus philander* (Weber, 1897)	4	3	2	3.5
TSPA*	*Tilapia sparrmanii* (Smith, 1840)	3	2	1	2.5
Introduced species					
OMOS*	*Oreochromis mossambicus* (Peters, 1852)	0	2	4	0

* Sampled at EWR site during baseline survey (June 2010).

7.5 MACROINVERTEBRATES

7.5.1 SASS data

Available SASS5 data collected at or near Site EWR O5 are summarised in Table 7.9.

Table 7.9 EWR O5: Available SASS 5 data

MRU	MRU Orange G			
Site	**OSAEH 28_5**	**S1**	**OSAEH 28_5**	**EWR O5**
Reference	**Chutter (1996)**	**Palmer (2004)**	**ORASECOM (2011a)**	**Louw *et al.*, 2013b**
Date	Nov 95	Jan 04	Nov 10	Jun 12
Flow (m^3/s)	-	-	-	Moderate
Biotope Suitability	-	-	-	61% (B)
SASS5 Score	160	152	150	125
No of Taxa	25	25	24	21
ASPT	6.4	6.1	6.3	5.9
PES: Ecological Traits (Category A - F)				80% (B/C)
PES: MIRAI (Category A - F)	-	-	79% (B/C)	78% (B/C)

7.5.2 Indicator taxa

Perlidae, Baetidae (>2 spp.), Tricorythidae, Atyidae, Elmidae, and Hydropsychidae (2 spp.) were selected as monitoring indicators for EWR O5. Table 7.10 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 7.10 EWR O5: Habitat preference of macroinvertebrate 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

7.5.3 EcoSpecs and TPCs

EcoSpecs and TPCs for the PES, Sc C2b and Sc A2 at EWR O5 are provided in Table 7.11.

Table 7.11 EWR O5: EcoSpecs and TPCs for macroinvertebrates (PES, PERC and Post Dam Sc: B/C)

EcoSpecs: PES	EcoSpecs: REC	TPCs
SASS5 Score >125	>150	SASS5 Score <130
ASPT >5.9	Same	ASPT <6.0
MIRAI Score >60%	>80%	MIRAI Score <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.

8 ESTUARIES: ECOSPECS AND TPCs

8.1 ORANGE ESTUARY: ECOSPECS IN TERMS OF ECOLOGICAL CATEGORIES

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 comprises 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 salt marsh on the south bank of the river mouth.

The ECs representative of broad qualitative EcoSpecs for the Orange Estuary is provided in Table 8.1 (modified from Van Niekerk *et al*., 2013). 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. However, in the short-term it may not be possible to achieve the REC (a low Category C). The major difference between the REC and the Preliminary Ecological Reserve Category (PERC) (Category C/D) is the degree to which the hydrodynamics (mouth state) can match the Reference Condition.

Table 8.1 EcoSpecs as ECs at the Orange Estuary

Components	PES	PERC	Actions
Hydrology	D	D	Decrease baseflows in winter under current configuration*. (see section 1.2)
Hydrodynamics	C	C	Increase retention time in winter (this could possibly also facilitate mouth closure under turbulent sea conditions).
Water quality	D	C	Reduce nutrient input in lower Orange River.
Physical habitat alteration	B	B	No improvement required.
Microalgae	E	D	Decrease nutrient input and reduce base flows in winter where possible under current configuration.
Macrophytes	D	C	Reduce nutrient input, remove causeway, control grazing and alien vegetation, reduce soil salinities.
Invertebrates	D	C	Reduce baseflows in winter under current configuration.
Fish	D	C	Reduce baseflows in winter under current configuration, control fishing.
Birds	E	D	Reduce baseflows in winter under current configuration.
EcoStatus	D	C/D	Reduce flows under current configuration, allow for sporadic mouth closure under turbulent sea conditions, and improve vegetation cover and food sources (invertebrates and fish).

*While Sc A2 and A3 does not show substantial benefits for the estuarine ecology indications are that further refinements can possibly facilitate low enough flows under the present configuration to allow for mouth closure under turbulent sea conditions.

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 salt marshes 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 salt marshes 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.

While Sc A2 and A3, generated as part of this study, did not show substantial benefits for the estuarine ecology, indications are that further refinements can possibly facilitate low enough flows under the present configuration to allow for mouth closure under turbulent sea conditions. It is therefore recommended that as part of Classification further refinements is made to see what incremental benefits can be achieved under the current configuration.

8.1.1 Orange Estuary: Abiotic EcoSpecs and TPCs

The EcoSpecs and TPCs for the abiotic components (hydrology, hydrodynamics, water quality, and sediment dynamics) of the Orange Estuary (Table 8.2) are based on the PREC of a C/D. This can be achieved through a range of non-flow related interventions and redistribution of the current base flow regime (Sc A2 or A3). Note that desirable flow ranges are being recorded at the Sendelingsdrif gauge for short periods (weeks) at a time.

Table 8.2 Orange Estuary: EcoSpecs and TPCs for abiotic components

EcoSpec	TPC
Hydrology	
Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	**Low flow requirement for mouth closure (D8H015 Sendelingsdrif):** ▪ Range: < 2 m^3/s (currently achieved 1.6% of time at D8H015). ▪ Duration: 1 month at a time during the low flow period. **Low flow requirement to maintain water column (instream) habitat:** ▪ 10% <5 m3/s (currently achieved 3.4% of time at D8H015). ▪ 20% <20 m3/s (currently achieved at D8H015)
Hydrodynamics	
Maintain a mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	**In-stream habitat:** ▪ The water column (in stream) habitat not be severely constricted/reduced for longer than 3 months at a time. **Mouth Closure:** ▪ Aperiodical mouth closure for less than 3 months in duration. **Water level during closed state:** ▪ >2.5 m mean sea level.
Water quality	
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 flows):** ▪ 20 < salinity > 30 lower reaches for 5 < months > 7 of the year. ▪ 0 < salinity > 5 upper reaches for 5 < months > 7 of the year. **River inflow (high flows):** ▪ Salinity <1 for >7 months of the year.
System variables (pH, DO and turbidity) not to exceed TPCs for biota (see above)	**River inflow (low flows):** ▪ 6.5< pH >8.5. ▪ DO <4 mg/l. ▪ Turbidity: Naturally turbid (can range between 10 - 100 NTU). **River inflow (high flows):** ▪ 6.5< pH >8.5. ▪ DO <4 mg/l. ▪ Turbidity: Naturally turbid (can be >200 NTU). **Estuary (low flows):** ▪ 6.5< pH >8.5. ▪ DO <4 mg/l.

EcoSpec	TPC
	Estuary (high flows): ▪ 6.5< pH >8.5. ▪ DO <4 mg/l.
Inorganic nutrient concentrations not to cause in exceedance of TPCs for macrophytes and microalgae (see above)	**River inflow (low flows):** ▪ DIN >100 µg/l; DRP >30 µg/l. **River inflow (high flows):** ▪ DIN >150 µg/l; DRP >30 µg/l. **Estuary (low flows):** ▪ DIN >100 µg/l; DRP >30 µg/l (except during upwelling when concentrations in saline areas can be higher). **Estuary (high flows):** ▪ DIN >150 µg/l; DRP >30 µg/l.
Presence of toxic substances not to cause exceedence of TPCs for biota (see biotic components above)	**River inflow:** ▪ Trace metals (apply Freshwater Quality Guidelines (DWAF, 1996)). ▪ Pesticides/herbicides (to be determined). **Estuary:** ▪ Trace metals: Concentrations in estuary waters exceed target values as per *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. ▪ 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%.

Post-dam Ecospecs that should be incorporated into the RQOs for the Orange Estuary should include more stringent flow and hydrodynamic (i.e. mouth closure) requirements as stated below in Table 8.3.

Table 8.3 Orange Estuary: EcoSpecs and TPCs for abiotic components for long-term targets post-dam construction to achieve a Category C

EcoSpec	TPC
Hydrology	
Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	**Low flow requirement for mouth closure (D8H015 Sendelingsdrif):** ▪ Range: < 2 m^3/s (currently achieved 1.6% of time at D8H015). ▪ Duration: 2 - 3 months at a time during the low flow period. ▪ Frequency: 2 - 4 years out of 10. **Low flow requirement to maintain water column (instream) habitat:** ▪ 10% <5 m3/s (currently achieved 3.4% of time at D8H015). ▪ 20% <20 m3/s (currently achieved at D8H015)
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 during closed state:** ▪ >2.5 m mean sea level. **In-stream habitat:** ▪ The water column (in stream) habitat not be severely constricted/reduced for longer than 3 months at a time.

8.1.2 Orange Estuary: Biotic EcoSpecs and TPCs

The EcoSpecs and TPCs for the biotic components (microalgae, macrophytes, invertebrates, fish and birds) of the Orange Estuary (Table 8.4) for a PERC of a C/D EC.

Table 8.4 Orange Estuary: EcoSpecs and TPCs for biotic components

EcoSpec	TPC
Microalgae	
Phytoplankton biomass and cell density should not exceed 20 µg/l [1] and 10 000 cells/ml (typical of blooms) respectively. Median phytoplankton and microphytobenthos (MPB) biomasses should not exceed 8 µg/l and 42 mg/m^2 (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. Median biomass in August 2012 (flow 20 - 50 m^3/s) exceeded these TPCs; Phytoplankton 13.1 µg/l and MPB 48.5 mg/m^2, and cell density was >31 000 cells/ml.	▪ Median phytoplankton chl-a should be <8 µg/l under 'normal flows'. ▪ Phytoplankton cell density should be >10 000 cells/ml 'normal flows'. ▪ Median MPB biomass should not be >42 mg/m^2 under 'normal flows'.
Macrophytes	
Maintain the diversity of macrophyte habitats in the estuary. Reeds and sedges covering approximately 300 ha, submerged macrophyte *Stuckenia pectinata* (pondweed) occurs in sheltered areas (approximately 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 (approximately 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/D Category the higher densities need to be highly variable in terms of abundance within and between years. Aperiodically mouth closure would the highly beneficial to the restoration of this system, but any variability in low flows would facilitate recovery of invertebrate community. 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 >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 don not recruit, *L. richardsonii* <90% biomass.
Birds	
The estuary should contain a rich avifaunal community that includes representatives of all the original groups,	Bird numbers should not continue on a downward trajectory.

<table>
<tr><th>EcoSpec</th><th>TPC</th></tr>
<tr><td>significant numbers of migratory waders and terns, as well as a healthy breeding population of resident waders. The estuary should support over 8000 waterbirds in summer and over 6000 birds in winter.</td><td>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 average numbers reported by Anderson et al. (2003):
<table>
<tr><td>Blacknecked Grebe</td><td>125</td></tr>
<tr><td>Great White Pelican</td><td>473</td></tr>
<tr><td>Cape Cormorant</td><td>984</td></tr>
<tr><td>Lesser Flamingo</td><td>1031</td></tr>
<tr><td>Greater Flamingo</td><td>700</td></tr>
<tr><td>South African Shelduck</td><td>516</td></tr>
<tr><td>Cape Shoveller</td><td>373</td></tr>
<tr><td>Chestnutbanded Plver</td><td>97</td></tr>
<tr><td>Pied Avocet</td><td>891</td></tr>
<tr><td>Curlew Sandpiper</td><td>1666</td></tr>
<tr><td>Kelp Gull</td><td>1098</td></tr>
<tr><td>Hartlaub's Gull</td><td>707</td></tr>
<tr><td>Caspian Tern</td><td>165</td></tr>
<tr><td>Swift Tern</td><td>344</td></tr>
<tr><td>Damara Tern</td><td>58</td></tr>
</table></td></tr>
</table>

8.2 SMALL WEST COAST ESTUARIES' ECOSPECS

The Small West Coast Estuaries EcoSpecs were derived from expert opinion and limited field data collected as part of this study. Individual components that needs improvement to maintain or meet the PERC where indicated with (↑). For more detail see DWS (2017).

8.2.1 BUFFELS ESTUARY

<table>
<tr><td>PES:</td><td>D (downwards trajectory)</td><td>PERC:</td><td colspan="2">D</td></tr>
<tr><td colspan="5">The system is on a negative trajectory of change and therefore requires the following interventions to maintain the PERC:

Remove roads/causeways dividing the estuary in three isolated sections (i.e. remnant of mining road at mouth; road at bird hide; road above the golf course).
Improve connectivity with catchment by increasing/establishing culverts in roads in catchments.
Remove invasive alien plants (rooikrans) in upper reaches (in progress).
Enforce the no driving on the beach legislation to allow for natural sediment processes to re-establish themselves and protect birds (in progress).
Investigate mitigations to reduce nutrient enrichment from golf course irrigation.
</td></tr>
<tr><td colspan="5">Flow</td></tr>
<tr><td>PES (PERC)</td><td colspan="2">nMAR (MCM)</td><td>Reference groundwater discharge (Mm^3/a)</td><td>Present groundwater discharge (Mm^3/a)</td></tr>
<tr><td rowspan="2">D/E</td><td colspan="2">11.2</td><td>0.23</td><td>-0.84</td></tr>
<tr><td colspan="4">
Flows should not exceed natural and seasonal distribution should not be compromised. Current baseflows should be upheld into estuary to maintain present mouth state and salinity regime. The distribution patterns of the flood components differ by no more than 10% (in terms of magnitude, timing and variability) from that of the Present (2015).
Groundwater needs to be maintained at present levels.
Floods need to reach the estuary.
</td></tr>
<tr><td colspan="5">Sediment processes</td></tr>
<tr><td>D</td><td colspan="4">
The flood regime maintains the sediment distribution patterns and aquatic habitat (instream physical habitat). The suspended sediment concentration from river inflow does not deviate by more than 20% of the present sediment load-discharge relationship (to be determined). The sedimentation and erosion patterns in the estuary do not differ significantly from present (± 0.5 m) (to be determined).
Changes in sediment grain size distribution patterns similar to present. The median bed
</td></tr>
</table>

	sediment diameter deviates by less than a factor of two from present levels (levels to be determined). The sand/mud distributions in middle and upper reaches do not change by more than 20% from Present State over a five year average.
Mouth state	
D	Mouth open conditions should be maintained within the current range, but the rate at which it breaches needs to increase (only take a short time to breach).
Water quality: Salinity	
D	The system needs variability in salinity regime, with a measurable increase in salinity in the upper and middle reaches during the winter season. ▪ Upper reaches: < 5 PSU. ▪ Lower reaches: < 20 PSU.
Water quality: Ecosystem health	
D	▪ DIN: Entire estuary, average <0.3 mg/l (aim for Category C). ▪ DIP: Entire estuary, average >0.025 mg/l (aim for Category C). ▪ DO: Entire estuary, average $\geq$4 mg/l. ▪ Turbidity: Entire estuary, average <20 NTU except during floods. Toxic substances: ▪ Substance concentrations in estuarine waters not to exceed targets as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995). ▪ Substance concentrations in estuarine sediment not to exceed targets as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Microalgae	
D	▪ Maintain the distribution of different phytoplankton groups (diverse community composition). ▪ Control nutrient input from golf course to prevent microalgal blooms (>20 µg/l).
Macrophytes	
E (↑)	▪ Maintain the distribution of current macrophyte habitats, <20% change in the area covered by different macrophyte habitats (accounts for natural changes due to the dynamic nature of estuaries). ▪ Maintain habitat diversity including some freshwater wetland with reeds and rushes and submerged macrophytes such as pondweed (*Stukenia pectinata*). ▪ Growth of natural vegetation in areas where rooikrans is being removed.
Invertebrates	
D	As sampled by plankton net, grab and dip nets/traps (as appropriate): Population abundances of plankton and benthic assemblages (baselines to be set) should not deviate by more than 25% at any point in the opening and closure cycle. Invasive alien species should not occur.
Fish	
E (↑)	As sampled by seine in open waters: ▪ 2 to 3 species should occur and include estuarine resident and estuarine dependant marine fishes. ▪ No alien fish species should occur. ▪ Fish should be free of lesions and other anomalies related to water quality. ▪ No fish kills should occur.
Birds	
D	Should be dominated by waders and water birds that comprise >15 species and >100 individuals. The occurrence and cause of bird mortalities needs to be verified.

8.2.2 SWARTLINTJIES ESTUARY

PES:	B	PERC:	B
Recommendations on how to maintain the PERC include: ▪ Develop an Estuary Management Plan (in progress) to evaluate to what extend old slimes dam is impacting on estuary and how functionality can be restored if required. ▪ Protect groundwater input to ensure hypersalinity is below <150 PSU (brine shrimp goes to cyst). ▪ Restore catchment connectivity (i.e. improve surface water flow) - increase culvert size / culverts at			

ground level in road crossings. ▪ Estuary in the process of recovering from previous mining activities, allow this process to continue. ▪ A concern is the impact of future mining prospects.			
Flow:			
PERC	**nMAR (MCM)**	**Reference groundwater discharge (Mm^3/a)**	**Present groundwater discharge (Mm^3/a)**
B	1.2	0.63	0.59
	▪ Flows should not exceed natural and seasonal distribution should not be compromised. Current baseflows should be upheld into estuary to maintain present mouth state and salinity regime. The distribution patterns of the flood components differ by no more than 10% (in terms of magnitude, timing and variability) from that of the Present (2015). ▪ Groundwater needs to be maintained at present levels. ▪ Floods need to reach the estuary.		
Sediment processes			
B	▪ The flood regime maintains the sediment distribution patterns and aquatic habitat (instream physical habitat). The suspended sediment concentration from river inflow does not deviate by more than 20% of the present sediment load-discharge relationship (to be determined). The sedimentation and erosion patterns in the estuary do not differ significantly from present (± 0.5 m) (to be determined). ▪ Changes in sediment grain size distribution patterns similar to present. The median bed sediment diameter deviates by less than a factor of two from present levels (levels to be determined). The sand/mud distributions in middle and upper reaches do not change by more than 20% from Present State over a five year average.		
Hydrodynamics and Mouth state			
B	Mouth open conditions should be maintained within the current range.		
Water quality: Salinity			
B	Average salinity: <150 PSU (hyper salinity)		
Water quality: Other			
B	▪ DIN: Entire estuary, average <0.1 mg/l. ▪ DIP: Entire estuary, average >0.01 mg/l. ▪ DO: Entire estuary, average >6 mg/l. ▪ Turbidity: Entire estuary, average <10 NTU except during floods. Toxic substances: ▪ Substance concentrations in estuarine waters not to exceed targets as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995). ▪ Substance concentrations in estuarine sediment not to exceed targets as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).		
Microalgae			
B	Maintain the distribution of different phytoplankton groups and low biomass (<5 µg/l).		
Macrophytes (plants)			
C	▪ Maintain the distribution of current macrophyte habitats, <20% change in the area covered by different macrophyte habitats (accounts for natural changes due to the dynamic nature of estuaries). ▪ Water column salinity not greater than 150 PSU to limit salt accumulation and dieback of salt marsh (*Sarcocornia pillansii*). Investigate historical slime dams input to ensure no salt input. ▪ Prevent further disturbance and development in the salt marsh and floodplain habitat.		
Invertebrates			
C/D	As sampled by plankton net, grab and dip nets/traps (as appropriate): ▪ Unincysted brine shrimp should be present in the system for 75% of the time.		
Fish			
B	Not applicable. Hyper saline system.		
Birds			

A/B	▪ Including flamingos, more than 10 species of waders and water birds that feed on brine shrimp should be present 75% of the time (during 40 – 150 PSU and brine shrimp available). ▪ The occurrence and cause of bird mortalities needs to be verified.

8.2.3 SPOEG ESTUARY

PES:	A/B	PERC:	A/B
Recommendations on how to maintain the PERC include: ▪ Restore / protect groundwater inflow. ▪ Allow regrowth of vegetation on derelict access roads crossing the upper reaches to continue; and ▪ Investigate the impact of proposed mining: Wind blow sand and increase in salinity via surface/ground water flow.			
Flow			
PERC	**nMAR (MCM)**	**Reference groundwater discharge (Mm³/a)**	**Present groundwater discharge (Mm³/a)**
B/C	1.3	0.36	0.22
B/C	▪ Flows should not exceed natural and seasonal distribution should not be compromised. Current baseflows should be upheld into estuary to maintain present mouth state and salinity regime. The distribution patterns of the flood components differ by no more than 10% (in terms of magnitude, timing and variability) from that of the Present (2015). ▪ Groundwater needs to be maintained at present levels. ▪ Floods need to reach the estuary.		
Sediment processes			
B	▪ The flood regime maintains the sediment distribution patterns and aquatic habitat (instream physical habitat). The suspended sediment concentration from river inflow does not deviate by more than 20% of the present sediment load-discharge relationship (to be determined). The sedimentation and erosion patterns in the estuary do not differ significantly from present (± 0.5 m) (to be determined). ▪ Changes in sediment grain size distribution patterns similar to present. The median bed sediment diameter deviates by less than a factor of two from present levels (levels to be determined). The sand/mud distributions in middle and upper reaches do not change by more than 20% from Present State over a five year average.		
Mouth state			
B	Maintain current connectivity with the marine environment.		
Water quality: Salinity			
A/B	▪ The system needs variability in salinity regime, with a measurable increase in salinity in the lower and middle reaches during the winter season. ▪ Average Salinity: <35 PSU.		
Water quality: Other			
A/B	▪ DIN: Entire estuary, average <0.1 mg/l. ▪ DIP: Entire estuary, average >0.01 mg/l. ▪ DO: Entire estuary, average >6 mg/l. ▪ Turbidity: Entire estuary, average <10 NTU except during floods. Toxic substances: ▪ Substance concentrations in estuarine waters not to exceed targets as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995). ▪ Substance concentrations in estuarine sediment not to exceed targets as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).		
Microalgae			
A/B	▪ Maintain the distribution of different phytoplankton groups and low biomass in the lower reaches (<10 µg/l).		
Macrophytes (plants)			
A	▪ Maintain the distribution of current macrophyte habitats, (<20% change in the area covered by different macrophyte habitats (accounts for natural changes due to the dynamic nature of estuaries).		

	▪ Maintain the salinity gradient to ensure habitat diversity including some freshwater wetland with reeds upstream and submerged macrophytes such as *Ruppia cirrhosa*. ▪ Prevent any further groundwater abstraction and increase in salinity that will lead to die-back of reeds and increase in dry bare saline areas in the salt marsh.
Invertebrates	
A	As sampled by plankton net, grab and dip nets/traps (as appropriate): ▪ Population abundances of plankton and benthic assemblages (baselines to be set) should not deviate by more than 25% at any point in the opening and closure cycle. ▪ Invasive alien species should not occur.
Fish	
A	As sampled by seine in open waters: ▪ 2 to 4 species should occur and include estuarine resident and estuarine dependant marine fishes. ▪ No alien fish species should occur. ▪ Fish should be free of lesions and other anomalies related to water quality. ▪ No fish kills should occur.
Birds	
A	▪ Should be dominated by waders and water birds that comprise >15 species and >50 individuals. ▪ The occurrence and cause of bird mortalities needs to be verified.

8.2.4 GROEN ESTUARY

PES:	**B**	**PERC:**	**A/B**
Components that require interventions or protection to achieve the PERC: ▪ **Hydrology:** Maintain groundwater flow to near natural levels. ▪ **Hydrology:** The estuary has a strong dependency on groundwater fed springs to maintain salinity gradient, maintain water levels, limit occurrence of extreme hyper salinity (<150 PSU). ▪ **Water Quality:** Improve water quality: Investigate possible organic/nutrient seepage from ablution facilities of offices/homes at SANParks and means to address these. ▪ **Sediment processes and Macrophytes:** Future pressures include an escalation of mining activities in the national park and related disruption of subsurface flow.			
Flow			
PES (PERC)	**nMAR (MCM)**	**Reference groundwater discharge (Mm^3/a)**	**Present groundwater discharge (Mm^3/a)**
C (↑)	5.5	0.13	0.08
	▪ Flows should not exceed natural and seasonal distribution should not be compromised. Current baseflows should be upheld into estuary to maintain present mouth state and salinity regime. The distribution patterns of the flood components differ by no more than 10% (in terms of magnitude, timing and variability) from that of the Present (2015). ▪ Groundwater needs to be maintained at present levels. ▪ Floods need to reach the estuary.		
Sediment processes			
A	▪ The flood regime maintains the sediment distribution patterns and aquatic habitat (instream physical habitat). The suspended sediment concentration from river inflow does not deviate by more than 20% of the present sediment load-discharge relationship (to be determined). The sedimentation and erosion patterns in the estuary do not differ significantly from present (± 0.5 m) (to be determined). ▪ Changes in sediment grain size distribution patterns similar to present. The median bed sediment diameter deviates by less than a factor of two from present levels (levels to be determined). The sand/mud distributions in middle and upper reaches do not change by more than 20% from Present State over a five year average.		
Hydrodynamics and Mouth state			
C	Mouth open conditions should be maintained within the current range.		
Water quality: Salinity			
B	▪ Upper reaches: <80 PSU (hyper salinity).		

	▪ Middle Reaches: <100 PSU (hyper salinity). ▪ Lower reaches: <150 PSU (hyper salinity).
Water quality: Other	
B	▪ DIN: Entire estuary, average <0.1 mg/l. ▪ DIP: Entire estuary, average >0.01 mg/l. ▪ DO: Entire estuary, average ≥6 mg/l. ▪ Turbidity: Entire estuary, average <15 NTU except during floods. Toxic substances: ▪ Substance concentrations in estuarine waters not to exceed targets as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995). ▪ Substance concentrations in estuarine sediment not to exceed targets as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Microalgae	
B (↑)	Maintain the distribution of different phytoplankton groups along the salinity gradient.
Macrophytes (plants)	
B	▪ Maintain the distribution of current macrophyte habitats (<20% change in the area covered by different macrophyte habitats (accounts for natural changes due to the dynamic nature of estuaries). ▪ Maintain the salinity gradient to ensure habitat diversity including the upstream freshwater seepage area where salinity should be less than 10 PSU. ▪ Prevent any further groundwater abstraction and increase in salinity that will lead to die-back of reeds and increase in dry bare saline areas in the salt marsh.
Invertebrates	
C	As sampled by plankton net, grab and dip nets/traps (as appropriate): ▪ Unencysted brine shrimp should be present in the system for 75% of the time.
Fish	
B	As sampled by seine in open waters: ▪ Two species *(M. cephalus, L. richardsonii)* should occur when salinities are less than 50 PSU in the salinity cycle. ▪ No alien fish species should occur. ▪ Fish should be free of lesions and other anomalies related to water quality. ▪ No fish kills should occur.
Birds	
B	▪ Including flamingos, more than 10 species of waders and water birds that feed on brine shrimp should be present 75% of the time (during 40 – 150 PSU and brine shrimp available). ▪ The occurrence and cause of bird mortalities needs to be verified.

8.2.5 SOUT ESTUARY

PES:	E	PERC:	D/E Classification should set TEC= D long term target)
Components that require interventions to achieve the PERC (and ultimately the REC): ▪ **Flow, hydrodynamics, sediment processes and macrophytes:** Develop an Estuary Management to evaluate to what extent the current design and/or operations of the salt works can be improved to restore estuarine habitat and functionality of the upper reaches. In progress - the Western Cape Government has prioritised this system for a plan. ▪ **Hydrodynamics:** Improve circulation (e.g. culverts in roads). ▪ **Flow:** Restore connectivity with catchment, i.e. investigate if weir can be partially removed to allow connectivity with western arm of estuary.			
Flow			
PES (PERC)	**nMAR (MCM)**	**Reference groundwater discharge (Mm^3/a)**	**Present groundwater discharge (Mm^3/a)**
D/E (↑)	0.7	1.24	1.13
	▪ Flows should not exceed natural and seasonal distribution should not be compromised. Current baseflows should be upheld into estuary to maintain present mouth state and salinity regime. The distribution patterns of the flood components differ by no more than 10% (in terms of magnitude, timing and variability) from that of the Present (2015). ▪ Groundwater needs to be maintained at present levels. ▪ Floods need to reach the estuary (at present significantly reduced by weir above estuary).		
Sediment processes			
E	▪ The flood regime maintains the sediment distribution patterns and aquatic habitat (instream physical habitat).The suspended sediment concentration from river inflow does not deviate by more than 20% of the present sediment load-discharge relationship (to be determined). The sedimentation and erosion patterns in the estuary do not differ significantly from present (± 0.5 m) (to be determined). ▪ Changes in sediment grain size distribution patterns similar to present. The median bed sediment diameter deviates by less than a factor of two from present levels (levels to be determined). The sand/mud distributions in middle and upper reaches do not change by more than 20% from Present State over a five year average.		
Hydrodynamics and Mouth state			
E/F (↑)	Improved connectivity with the different water bodies and restored connectivity with the catchment through removal/modification of weir at the head of the estuary.		
Water quality: Salinity			
E (↑)	Upper reaches: <120 PSU (hyper salinity). Middle Reaches: <80 PSU (hyper salinity). Lower reaches: <60 PSU (hyper salinity).		
Water quality: Other			
D	▪ DIN: Entire estuary, average <0.1 mg/l. ▪ DIP: Entire estuary, average >0.01 mg/l. ▪ DO: Entire estuary, average ≥6 mg/l. ▪ Turbidity: Entire estuary, average <10 NTU except during floods Toxic substances: ▪ Substance concentrations in estuarine waters not to exceed targets as per SA Water Quality Guidelines for coastal marine waters (DWAF, 1995). ▪ Substance concentrations in estuarine sediment not to exceed targets as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).		
Microalagae			
E (↑)	Maintain the distribution of different phytoplankton groups and low biomass in the lower reaches (< 10 µg/l.		
Macrophytes (plants)			
E/F (↑)	▪ Maintain the distribution of current macrophyte habitats, (<20% change in the area covered by		

	different macrophyte habitats (accounts for natural changes due to the dynamic nature of estuaries). ▪ Water column salinity not greater than 50 PSU in the lower reaches to limit salt accumulation and dieback of salt marsh (*Sarcocornia pillansii*). ▪ Prevent further disturbance and development in the salt marsh and floodplain habitat through salt works activities.
Invertebrates	
E (↑)	As sampled by plankton net, grab and dip nets/traps (as appropriate): ▪ Unincysted brine shrimp should be present in the system for 75% of the time.
Fish	
E/F (↑)	Not applicable. Hyper saline system.
Birds	
E (↑)	▪ Including flamingos, more than 10 species of waders and water birds that feed on brine shrimp should be present 75% of the time (during 40 – 150 PSU and brine shrimp available). ▪ The occurrence and cause of bird mortalities needs to be verified.

9 ESTUARIES: MONITORING RECOMMENDATIONS

9.1 ORANGE ESTUARY: EXISTING 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 9.1 and the additional work is required to improve the confidence in the baseline is also provided.

Table 9.1 Orange Estuary: Existing baseline survey data and additional recommendations to support the baseline information

Baseline Survey	Data available
Existing baseline	
Hydrology	
Continuous river flow gauging at the head of the estuary (e.g. Brandkaros).	No, only long-term data available from Vioolsdrift 1935 to 2016. The recently installed flow gauge Sendelingsdrift has insufficient data at this stage.
Hydrodynamics	
Additional continuous water level recordings near mouth of the estuary and in the salt marsh area near the beach.	Only at the bridge.
Daily observations on the state of the mouth, if the mouth is closed or almost closed state.	No.
Aerial photographs of estuary - colour, geo-referenced rectified aerial photographs at 1: 5 000 scale covering the entire estuary (based on the geographical boundary), and taken at low tide in summer, are required. These photographs must include the breaker zone near the mouth.	1937, 1943, 1951, 1962, 1964, 1976, 1977, 1979, 1980, 1987, 1988, 1990.
Sediment	
Series of cross-section profiles along the beach, bar, mouth and lower basin region (at about 25 m intervals) as well as upstream along the entire estuary (at ~300 m intervals from the +5 m MSL contour on the left bank, through the estuary to the +5 m MSL contour on the right bank), using D-GPS and echo-sounding). This should be done every 3 years (and immediately after a flood) to quantify the sediment deposition rate in the estuary.	Partial: 1987, 1988, 1990.
Series of sediment grab samples for the analysis of Particle Size Distribution (PSD), cohesive nature and organic content, taken every 3 years (and immediately after a flood) along the length of the estuary (at ~ 100 to 300 m intervals across the estuary including the inter- and supratidal areas). Representative samples should also be collected from the adjacent beach and sand bar.	Partial: 1988, 2008.
A series of sediment core samples for historical sediment characterisation taken once-off, but ideally just after a medium to large flood as well as a year (or two) later along the same grid as the grab samples (see above).	No.
Sediment load near the head of estuary (including grain size distribution and particulate carbon - detritus component): Daily intervals for a minimum 5 years. Ideally, both suspended- and bed-load should be monitored. The measurements could be done at Brandkaros, but ideally within a few kilometres upstream of the Oppenheimer Bridge.	Upstream 1988.
Water quality	
Monthly water quality measurements on system variables (conductivity, temperature, pH, DO, turbidity, suspended solids), inorganic nutrients (e.g. nitrate, ammonium and reactive phosphate) and, if possible, toxic substances in river water entering at the head of the estuary (Oppenheimer Bridge). Ideally, particulate organic carbon input (see also sediment dynamics) should	Available Ernst Oppenheimer Bridge (D8H012Q01) and Vioolsdrift (D8H083Q01).

Baseline Survey	Data available
be recorded.	
Longitudinal salinity and temperature profiles (in situ) collected over a spring and neap tide during high and low tide at: ▪ Low flow season (i.e. period of maximum seawater intrusion), but when the mouth is still open. ▪ During mouth closure (this may require a series of surveys to capture the dynamic nature of this state).	Feb 2004, Aug 2004, Feb 2005, Feb 2012, Aug 2012.
Water quality measurements (pH, DO and turbidity) taken along the length of the estuary (surface and bottom samples) on a spring and neap high tide at: ▪ end of low flow season ▪ peak of high flow season	Once-off Jan 1979, Sep 1993, Feb 2004, Aug 2004, Feb 2005, Feb 2012, Aug 2012.
Water quality measurements (inorganic nutrients) taken along the length of the estuary (surface and bottom samples) on a spring and neap high tide at: ▪ End of low flow season. ▪ Peak of high flow season.	Once-off Jan 1979, Feb 2012 and Aug 2012.
Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary.	Trace metal in sediment (1979).
Microalgae	
Chlorophyll-a measurements taken at five stations (at least) at the surface, 0.5 m and 1 m depths thereafter. Cell counts of dominant phytoplankton groups including flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. Measurements should be taken coinciding with the different abiotic states, particularly State 1 (closed mouth) and State 5 (freshwater dominated). These data will complement existing data ('normal' flow).	Once-off August 2012 low flow RDM sampling session. Limited data from Harrison *et al*. (CSIR, unpub. data).
Intertidal and subtidal benthic chlorophyll-a measurements taken at five stations. Epipelic diatoms need to be collected for identification. Measurements should be taken coinciding with the different abiotic states, particularly State 1 (closed mouth) and State 5 (freshwater dominated). These data will complement existing data ('normal' flow).	Once-off August 2012 low flow RDM sampling session.
The microalgal survey must be done at the same time as the water quality survey.	Once-off August 2012 low flow RDM sampling session. Limited data from Harrison *et al*. (CSIR, unpub. data).
Macroalgae	
Aerial photographs of the estuary (ideally 1:5000 scale) reflecting the present state, as well as the reference condition (earliest year available). A GIS map of the estuary must be produced indicating the present and reference condition distribution of the different plant community types.	2012 GIS map from Spot 5 imagery (2010) and ground-truthing in August 2012.
Number of plant community types, identification and total number of macrophyte species, number of rare or endangered species or those with limited populations documented during a field visit. The extent of anthropogenic impacts (e.g. trampling, mining) must be noted.	Data available, updated from 2012 field survey.
Permanent transects (fixed monitoring stations that can be used to measure change in vegetation in response to changes in salinity and inundation patterns) must be set up along an elevation gradient: Measurements of percentage plant cover of each plant species in duplicate quadrats (1 m^2). Measurements of sediment salinity, water content, depth to water table and water table salinity.	Recent data not available although SAEON did sample transects in January 2012. Data set from 2006 used in this study.
Invertebrates	
Collect a set of benthic samples from ten sites, each consisting of six replicate grabs stored separately.	2004, 2005 and 2012.
Collect replicated hyperbenthic samples.at the same benthic sites (i.e. two replicates at each of the ten sites).	2004, 2005 and 2012.
Collect replicated zooplankton samples at each of the ten benthic sites (i.e. two replicates at each of the ten sites) at night.	2004, 2005 and 2012.

Baseline Survey	Data available
During each survey, collect sediment samples for analysis of grain size 1 and organic content 2 at the ten benthic sites. Compile a sediment distribution map of the estuary. Obtain a detailed determination of the extent and distribution of shallows and tidally exposed substrates.	2004, 2005 and 2012.
Fish	
The Orange Estuary needs to be sampled from the mouth to Brandkaros 35 km upstream.	Brown, 1959; Day, 1981; Cambray, 1984; Morant and O'Callaghan, 1990; Harrison, 1997; Seaman and van As, 1998; unpublished data: 2004, 2005 and 2012.
Seine-nets to sample small and juvenile fish and gillnets to sample adults are the appropriate gear.	Unpublished data: 2004, 2005 and 2012, 2015, 2016.
Birds	
Continue with full count of all water associated birds bi-annually covering as much of the estuarine area as possible, (as part of the requirements of Ramsar). All birds should be identified to species level and the total number of each counted.	Ryan and Cooper, 1985; Williams, 1986; Simmons, 1994, 1995; Taylor *et al.,* 1999; Anderson *et al*., 2003. Nov 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.
Sediment	
Sediment core samples along the entire estuary (10 - 20 m deep).	Once off.
Sample suspended sediment load at Vioolsdrift.	Daily.
Invertebrates	
The Orange Estuary needs to be sampled quarterly over at least one year to account for the seasons.	Seasonal (i.e. quarterly).
Additional trip(s) may be required to gather data on the occurrence/recruitment and emigration of key that require a connection to the marine environment at specific times of the year.	
Fish	
The Orange Estuary needs to be sampled quarterly over at least one year to account for the seasons.	Seasonal (i.e. quarterly).
Given the evident links between the estuary and adjacent surfzone, it would also be advisable to sample the surf-zone with the seine-net, to at least 1 km either side of the mouth.	
Given the uncertainty as to the dominant food sources and the possible seasonal changes in them, a representative sample should be retained for stomach content analysis.	

9.2 DETAIL MONITORING STUDIES: ORANGE ESTUARY

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

Nutrient Assessment Programme: 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.

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).

Impact of sustained low flows on water column (in-stream) habitat and fish: Detailed Topographical/Bathymetry surveys of the Orange Estuary at low flows are required to determine at what flow ranges the habitat become unsuitable for fish. The geomorphic survey should be conducted at the same time as biological surveys on fish, invertebrates and birds.

Ecological Water Requirements of the nearshore Orange Marine Environment: The flow requirements of the nearshore Orange Marine Environment - declared an South African Ecologically or Biologically Significant Marine Areas (EBSA) under the Conversion on Biodiversity Conservation - need to be assed to quantify the impact of the proposed Vioolsdrift dam development on the provision of sediments, organics, nutrients and freshwater fronts to the beaches and nearshore marine environment. This aspect needs to be formally addressed as part of the Classification.

9.3 ESTUARY BASELINE AND LONG-TERM MONITORING REQUIREMENTS OF THE SMALL WEST COAST ESTUARIES IN SUPPORT OF HIGHER LEVEL EWR STUDIES

Recommended minimum monitoring requirements to ascertain impacts of changes in freshwater flow to the estuary and any improvement or reductions therein are listed in Table 9.2.

Table 9.2 Recommended minimum requirements for long-term monitoring (Priority: Red = High; Orange = Medium, Yellow = Low, White = Not relevant)

Com-ponent	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Buffels	Swart-lintjies	Spoeg	Groen	Sout
Hydrodynamics	Record estuary water levels.	Continuous	In main water body	Red	Red	Red	Red	Red
	Measure groundwater level.	Continuous	Near head of estuary	Red	Red	Red	Red	Red
	Satellite photographs of estuary (30x 30 m).	Every 3 years	Entire estuary	Red	Red	Red	Red	Red
Sediment dynamics	Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 100-200 m intervals, but in more detail in the mouth. The vertical accuracy should be about 5 cm.	Every 3 years	Entire estuary	Orange	Orange	Orange	Orange	Orange

Com-ponent	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Buffels	Swart-lintjies	Spoeg	Groen	Sout
	Set sediment grab samples (at cross section profiles) for analysis of PSD and origin (i.e. using microscopic observations).	Every 3 years (with invert sampling)	Entire estuary					
Water quality	Water quality (e.g. system variables (e.g. pH, oxygen, turbidity), nutrients and toxic substances) measurements in Groundwater entering the head of the estuary.	Monthly continuous	Close proximity to head of estuary					
	Sewage volume and concentrations.	Monthly continuous	At source	Golf course			SAN-Park office	
	In situ salinity and temperature observations.	Continuous	In main water body (1 to 3 stations)					
	Longitudinal salinity and temperature profiles (in situ) collected over a spring and neap tide during high and low tide at: ▪ End of low flow season (i.e. period of maximum seawater intrusion). ▪ Peak of high flow season (i.e. period of maximum flushing by river water).	Every year at end of dry season	Entire estuary (3 - 5 stations)					
	Water quality measurements (i.e. system variables, and nutrients) taken along the length of the estuary (surface and bottom samples).	Seasonal surveys, every 3 years	Entire estuary (3-5 stations)					
	Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary, where considered an issue.	Every 6 years	Focus on sheltered, depositional areas					
	Water quality (e.g. system variables, nutrients and toxic substances) measurements on near-shore seawater.	Use available literature	Seawater adjacent to estuary mouth at salinity 35					
Microalgae	Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms and blue-green algae.	Summer survey every 3 years	Entire estuary					
	Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. High-performance liquid chromatography (HPLC).	Summer survey every 3 years	Entire estuary					
	Intertidal and subtidal benthic chlorophyll-a measurements.	Summer survey every 3 years	Entire estuary					
Macrophy tes	Ground-truthed maps to document changes in macrophyte habitats over time. Document area covered by sensitive habitats i.e. submerged macrophytes.	Summer survey every 3 years	Entire estuary					

Com-ponent	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Buffels	Swart-lintjies	Spoeg	Groen	Sout
	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.	Summer survey every 3 years	Entire estuary					
	Note extent of macroalgal blooms, floating aquatic macrophytes and area occupied by invasive vegetation.	Summer survey every 3 years	Entire estuary					
	Take measurements of depth to water table and ground water salinity in reed beds.	Summer survey every 3 years	Upper reaches					
Invertebrates	Record species and abundance of zooplankton, based on samples collected across the estuary.	Summer survey every 3 years	Entire estuary (3 - 5 stations)					*Pale mo* popul ation
	Record benthic invertebrate species and abundance, based on subtidal and intertidal grab samples at a series of stations up the estuary, and counts of hole densities.	Summer survey every 3 years	Entire estuary (3 - 5 stations)					
	Measures of sediment characteristics at each station.	Summer survey every 3 years	Entire estuary (3 - 5 stations)					
Fish	Record species and abundance of fish, based on seine net sampling.	Summer survey every 3 years	Entire estuary (3 - 5 stations)					
Birds	Undertake counts of all water associated birds, identified to species level.	Annual winter (Jul/Aug) and summer (Jan/Feb) surveys	Entire estuary					

Recommended baseline monitoring requirements to improve on the confidence of future EWR assessments are listed in Table 9.3.

Table 9.3 Recommended baseline monitoring requirements (Priority: Red = High; Orange = Medium, Yellow = Low, White = Not relevant)

Com-ponent	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Buffels	Swart-lintjies	Spoeg	Groen	Sout
Hydrodynamics	Record estuary water levels.	Continuous	In main water body					
	Measure groundwater level.	Continuous	Near head of estuary					
	Satellite photographs of estuary (30x 30 m).	Once-off	Entire estuary					
Sediment dynamics	Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 100 - 200 m intervals, but in more detail in the mouth. The vertical accuracy should be about 5 cm.	Once-off (or in the case of a flood)	Entire estuary					

Com-ponent	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Buffels	Swart-lintjies	Spoeg	Groen	Sout
	Set sediment grab samples (at cross section profiles) for analysis of PSD and origin (i.e. using microscopic observations).	Once-off (with invert sampling)	Entire estuary					
Water quality	Water quality (e.g. system variables (e.g. pH, oxygen, turbidity), nutrients and toxic substances) measurements in Groundwater entering the head of the estuary.	Breaching event, then quarterly for 2 years	Close proximity to head of estuary					
	Sewage volume and concentrations.	Breaching event, then quarterly for 2 years	At source	Golf course			SAN Park office	
	In situ salinity and temperature observations.	Continuous	In main water body (1 to 3 stations)					
	Longitudinal salinity and temperature profiles (in situ) collected over a spring and neap tide during high and low tide at: ▪ End of low flow season (i.e. period of maximum seawater intrusion). ▪ Peak of high flow season (i.e. period of maximum flushing by river water).	Breaching event, then quarterly for 2 years	Entire estuary (3 - 5 stations)					
	Water quality measurements (i.e. system variables, and nutrients) taken along the length of the estuary (surface and bottom samples).	Breaching event, then quarterly for 2 years	Entire estuary (3 - 5 stations)					
	Measurements of organic content and toxic substances (e.g. trace metals and hydrocarbons) in sediments along length of the estuary, where considered an issue.	Breaching event, then quarterly for 2 years	Focus on sheltered, depositional areas					
	Water quality (e.g. system variables, nutrients and toxic substances) measurements on near-shore seawater.	Use available literature	Seawater adjacent to estuary mouth at salinity 35					
Microalgae	Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms and blue-green algae.	Breaching event, then quarterly for 2 years	Entire estuary					
	Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. HPLC.	Breaching event, then quarterly for 2 years	Entire estuary					
	Intertidal and subtidal benthic chlorophyll-a measurements.	Breaching event, then quarterly for 2 years	Entire estuary					
Macrophytes	Ground-truthed maps to document changes in macrophyte habitats over time. Document area covered by sensitive habitats i.e. submerged macrophytes.	Breaching event, then after 2 years	Entire estuary					

Com-ponent	Monitoring action	Temporal scale (frequency and when)	Spatial scale (no. stations)	Buffels	Swart-lintjies	Spoeg	Groen	Sout
	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.	Breaching event, then after 2 years	Entire estuary					
	Note extent of macroalgal blooms, floating aquatic macrophytes and area occupied by invasive vegetation	Breaching event, then after 2 years	Entire estuary					
	Take measurements of depth to water table and ground water salinity in reed beds.	Breaching event, then after 2 years	Upper reaches					
Invertebrates	Record species and abundance of zooplankton, based on samples collected across the estuary	Breaching event, then quarterly for 2 years	Entire estuary (3 - 5 stations)					*Palemo* population
	Record benthic invertebrate species and abundance, based on subtidal and intertidal grab samples at a series of stations up the estuary, and counts of hole densities.	Breaching event, then quarterly for 2 years	Entire estuary (3 - 5 stations)					
	Measures of sediment characteristics at each station.	Breaching event, then quarterly for 2 years	Entire estuary (3 - 5 stations)					
Fish	Record species and abundance of fish, based on seine net sampling.	Breaching event, then quarterly for 2 years	Entire estuary (3 - 5 stations)					
Birds	Undertake counts of all water associated birds, identified to species level.	Breaching event, then quarterly for 2 years	Entire estuary					

9.4 DETAIL MONITORING STUDIES: SMALL WEST COAST SYSTEMS

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

Salinity - Brine shrimp - Bird Dynamics Monitoring Programme: The Small West Coast estuaries play an important role as bird refuge areas. A critical food source for birds in this region is brine shrimp, which in turn is related to the occurrence of low and high salinities in the small systems, i.e. less than <50 PSU likely to be in very low numbers, >150 PSU likely to be in cyst form. A dedicated study needs to be undertaken that focuses on bird abundance and brine shrimp abundance coupled with in situ salinity observations in these small systems.

The role of ground water in maintaining the salinity gradient of the Groen Estuary: Ground water plays an important role in maintaining the springs that flow into the middle and upper reaches of the Groen Estuary (situated in the Namaqualand National Park). The springs, in turn, moderate the hyper salinity cycles that naturally occur in this system. The location of the springs needs to be mapped and their groundwater requirements established.

10 GROUNDWATER MONITORING

To determine water quality monitoring requirements, trace groundwater quality constituents in the Department of Water Affairs and Sanition ZQM database were analysed. Severeal chemical parameters that sometimes exceed potable standards were identified, these being Arsenic and Molybdendum.

To identify stressed areas in terms of water quantity, data on domestic groundwater use was collected from the All Towns strategy reports, and the Lower Orange ISP. Where no data was available from the All Towns studies, the ISP data was used. Schedule 1 water use was determined from the Census 2011 data water sources. The combined domestic water use from formal groundwater schemes and schedule 1 water users divided by total domestic water use determined the Groundwater Depenency. Livestock water use was obtained from GRAII and Irrigation, Mining and industrial water use from WARMS to obtain a total water use. The total water use relative to recharge is the stress index. Several areas have been identified as being stressed in terms of high stress indices, declining water levels, and sole source dependency. These are depicted in Figure 10.1. Most of the priority catchments are located in the south, the Karoo sandstone and shale Groundwater Resource Units (GRUs), which are the target area for potential fracking (DWS, 2016c).

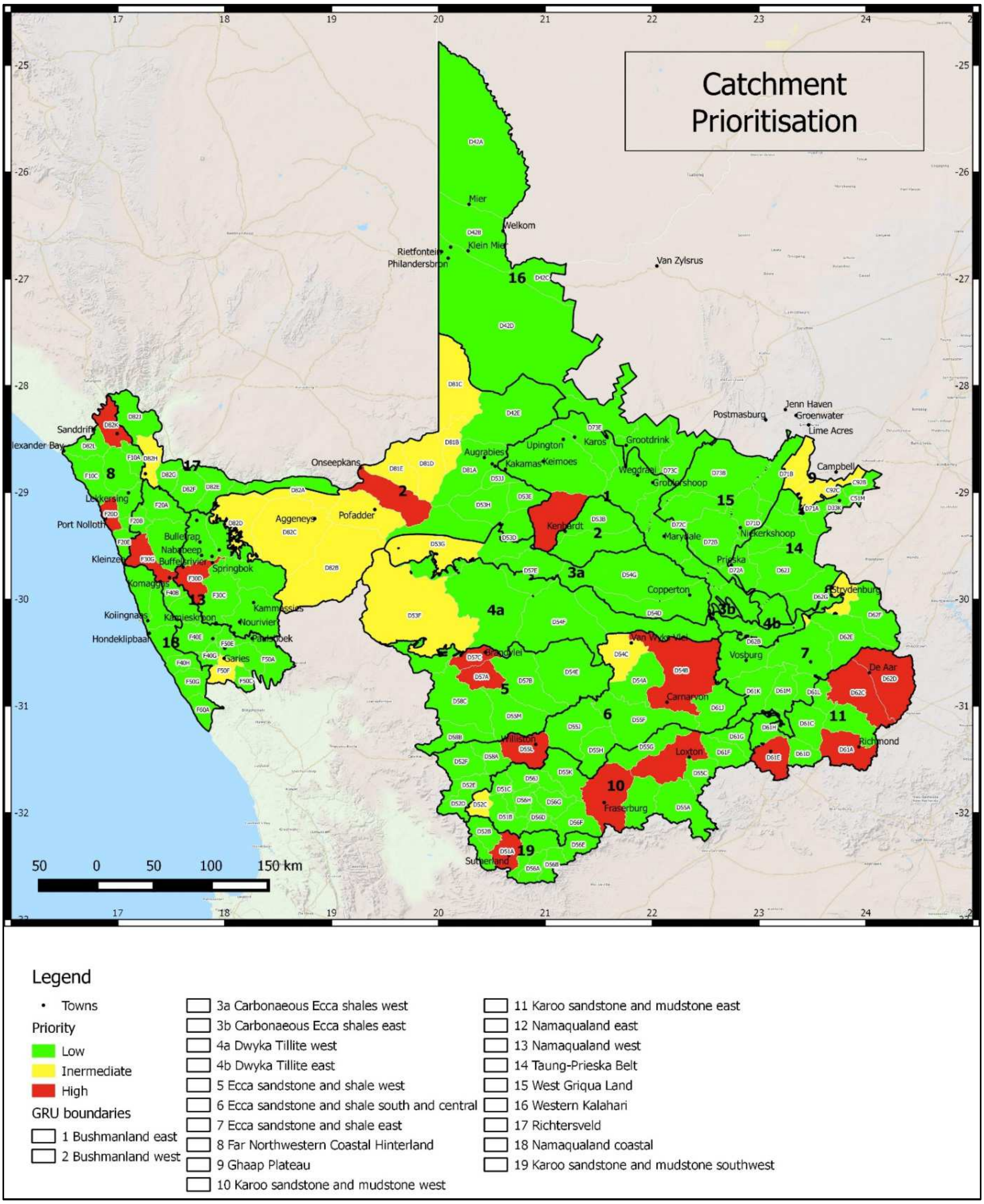

Figure 10.1 Catchment prioritisation of groundwater in the Lower Orange WMA

These GRUs are also classified as sole source aquifers for water supply, and highly dependent on groundwater with an already high stress index. Contamination or large abstractions from fracking or other activities could also cause significant deterioration in water supply. The specification of RQOs for these GRUs will require additional and stringent RQO attributes, which will need to be based on monitoring data.

Additional monitoring requirements for groundwater were identified based on the following key Indicators:

- Stressed catchments where groundwater use is a significant proportion of recharge, or where future use due to fracking and associated infrastructure, requires water use and water level monitoring.
- Good groundwater quality areas where hydraulic fracturing may occur.

Table 10.1 Monitoring programme for groundwater resources

GRU	Catchment	Priority	Ground water dependency (%)	Stress index	Main stresses	Water level monitoring requirements	Water quality monitoring[1]
Bushmanland East	D53C	High	77	1.08	Regional water schemes	Ground water level monitoring is required in the vicinity of Kenhardt.	Cadmium
	D72C	Low	89	0.17	Regional water schemes	Some localised water level drops of 1 m have occurred in the vicinity of Marydale.	
Bushmanland West	D81B	Intermediate	6	1.02	Livestock	No long term water level monitoring exists to evaluate trends hence existing boreholes need to continue being monitored.	Arsenic
	D81C	Intermediate	37	0.74	Livestock	No long term water level monitoring exists to evaluate trends hence existing boreholes need to continue being monitored.	Arsenic
	D81D	Intermediate	35	0.96	Livestock	No long term water level monitoring exists and monitoring is required.	Arsenic
	D81E	Intermediate	28	1.35	Livestock	No long term water level monitoring exists and monitoring is required.	Arsenic
	D81F	High	61	3.80	Livestock	No long term water level monitoring exists and monitoring is required.	Arsenic
	D81G	Intermediate	3	1.02	Livestock	No long term water level monitoring exists and monitoring is required in the vicinity of Pofadder.	Arsenic
	D82A	Intermediate	69	5.63	Livestock	No long term water level monitoring exists and monitoring is required.	Arsenic
	D82B	Intermediate	40	2.15	Livestock	No long term water level monitoring exists and monitoring is required.	Arsenic
	D82C	Intermediate	9	2.03	Livestock	No long term water level monitoring exists and monitoring is required in the vicinity of Aggeneys.	Arsenic
	D82D	Intermediate	4	0.66	Livestock	No long term water level monitoring exists and monitoring is required.	Arsenic
Dwyka Tillite	D53G	Intermediate	29	0.64	Livestock mining Regional schemes	No long term water level monitoring exists and monitoring is required in the vicinity of Copperton.	
Carbonaceous Shale	D53F	Intermediate	51	1.47	Mining Industry	No long term water level monitoring exists and monitoring is required in the vicinity of the Commissioner's Pan Salt Works.	Arsenic
Ecca Sandstone and Shale West	D57A	High	92	0.86	Irrigation	A high stress index is related to irrigation usage in the Water Authorisation and Management System	

GRU	Catchment	Priority	Ground water dependency (%)	Stress index	Main stresses	Water level monitoring requirements	Water quality monitoring[1]
						(WARMS). The actual existence of this irrigation needs to be verified	
	D57C	High	98	0.75	Regional schemes	Brandvlei utilises a significant volume of groundwater, however, no monitoring data is available.	
Ecca Sandstone and Shale Central and Southwest	D54B	High	98	0.26	Irrigation Regional schemes	Significant water level declines are occurring near Carnarvon and monitoring should be extended.	Arsenic
	D54C	Intermediate	87	0.22	Regional schemes	Water level trends near Van Wyk's Vlei are uncertain and monitoring should continue.	
	D55L	High	99	0.56	Irrigation	Significant water use registration for irrigation exists near Williston. Most water level monitoring was stopped in 2003 and the few sporadic data after 2010 exhibit uncertain trends.	
Ecca Sandstone and Shale East	D62G	Intermediate	95	0.05	Regional schemes	Water level data is sparse and of poor quality in the vicinity of Strydenburg, however, significant water level declines are evident.	Arsenic
	D62A	Low	98	0.06		Although the stress index is low, water levels are declining. Abstraction may be significantly higher than registered and should be monitored near Britstown.	Arsenic
Far Northwestern Coastal Hinterland	D82K	High	82	2.63	Regional schemes	Kuboes utilises a significant volume of groundwater, however, no monitoring data is available.	Arsenic
	F20D	High	55	2.78	Regional schemes	Port Nolloth utilises a significant volume of groundwater, however, very sparse monitoring data is available since 1990.	Arsenic
Ghaap Plateau (dolomitic)	C92B	Intermediate	52	0.06	Dolomites	Water level data is available only near Griekwastad in D71B. Monitoring should also be initiated in C92C between Cambell and Douglas.	Arsenic
	C92C	Intermediate	6	0.22			Arsenic
	D71A	Intermediate	61	0.02			Arsenic
	D71B	Intermediate	93	0.10			Arsenic
Karoo Sandstone and Shale West	D52C	Intermediate	92	0.74	Irrigation	A high stress index is related to irrigation usage in the WARMS. The actual existence of this irrigation needs to be verified.	Arsenic Molybdenum
	D55D	High	96	0.28	Irrigation Regional schemes	Significant water level declines are occurring near Loxton and monitoring should be extended.	Arsenic Molybdenum

GRU	Catchment	Priority	Ground water dependency (%)	Stress index	Main stresses	Water level monitoring requirements	Water quality monitoring[1]
	D55E	High	99	0.11	Regional schemes	Significant water level declines are occurring near Fraserburg and monitoring should be extended.	Arsenic Molybdenum
Karoo sandstone and Shale East	D61A	High	89	0.26	Irrigation Regional schemes	Significant water level declines are occurring near Richmond and monitoring should be extended.	Arsenic Molybdenum
	D61E	High	96	0.24	Regional schemes Irrigation	No long term historical data exists near Victoria West. Reliable data from only 1 borehole exists since 2009. The network needs to be extended.	Arsenic Molybdenum
	D62C	High	96	0.03	Irrigation Regional schemes	A suitable network exists however data since 2005 is sparse making monitoring and forecasting problematic.	Arsenic Molybdenum
	D62D	High	99	0.15	Regional schemes		Arsenic Molybdenum
Namaqualand East	F30D	High	55	1.8	Regional schemes	A significant groundwater use registration exists for Springbok, although the town is on surface water. This use needs to be verified. Groundwater level data is available only from 2014.	Arsenic
Namaqualand West	F30G	High	94	4.57	Mining	A high stress index is related to mining usage at Bontekoe Mining and De Beers Namaqualand in WARMS. The actual usage and its source irrigation need to be verified. No water level data is available and monitoring is required.	Arsenic Cadmium
	F50F	Intermediate	96	0.28	Regional schemes	Significant usage for the cluster from Garies to Kamaggas occurs however, monitoring data does not show a decline in water levels. Monitoring should continue.	Arsenic Cadmium
Richtersveld	D82H	Intermediate	97	0.42	Livestock Regional schemes	Groundwater usage occurs for Eksteenfontein, however no monitoring data is available. Monitoring should be initiated.	
Karoo sandstone and Shale Southwest	D51A	High	>99	0.23	Irrigation Regional schemes	Significant abstraction occurs for Sutherland and a water level decline is evident in the two available boreholes. The network needs to be extended since the catchment is nearly 100% reliant on groundwater.	

1 A blank cell under monitoring requrements means no additional monitoring is required as no water quality problem exists in the availbale data and the host geology does not suggest any additional monitoring is required.

11 PRELIMINARY RESERVE IMPLEMENTATION

11.1 BACKGROUND

"In the interim, there is still a need to influence decision-makers to amend the operating rules of dams, especially Vanderkloof, in order to simulate historical flow regimes, especially the sustained low winter flows required to close the mouth. A closer resemblance of future flow regimes at the estuary to historical patterns will result in the occasional flooding of the saltmarsh, opening and closing of the mouth and establishment of a larger area of mud-flats, all of which will result in additional feeding habitats for birds."

The above is an extract from the "Orange River Mouth RAMSAR Site Strategic Estuarine Management Plan" prepared by the Department of Environmental Affairs dated October 2015. It clearly states that a main intervention to improve the Estuary is linked to the operation of the system.

The current approach to manage and operate the Orange River Project (consisting of Gariep and Vanderkloof dams) is as follows:

1. Each year, prior to the annual operating analyses simulations, updated demands and projections are obtained from the existing users of the resource. These updated demand projections are included in the system simulation model in preparation for the annual analyses.
2. The observed dam storages on 1 May each year are obtained and also included as starting storages for all the major dams included in the model.
3. The system model is then used to carry out simulations, and an annual operating rule is prepared. The rule dictates three main operating conditions, namely:
    a. If surplus water is available in the system that can be allocated as an additional discretionary allowance to Eskom for the purpose of Hydropower generation.
    b. If the storage in the system is sufficient to provide all users with their allocations, or whether or not restrictions are required for the operating year. If restrictions are required, the extent of those restrictions amongst the various user sectors is determined.
    c. The release pattern that should be used for the operating year based on user requirements and the distribution of the demands over the year. Careful consideration is given to the distance between the main dams and the most downstream users, and a lag time is built into the proposed releases, such that the water reaches the required point at the desired time.

One "demand" that is standard each and every year, and which has not been updated, nor modified since its original inclusion in the late 1990's is known as the "Orange River Mouth Requirement". The demand is positioned downstream of all other users, and is supplied as a priority by the Orange River Project Dams in the model simulations. The total demand and the distribution pattern were first determined in the Orange River Development Project Replanning Study (DWAF, 1996b). Very little was known at the time about the river mouth or river requirements, and it was considered the best solution with the limited data and information available at the time. The demand (pulling from the Orange River Project - ORP) is currently simulated as a constant annual (i.e. same total demand each year), with a varying monthly distribution. The demand consists of two components as indicated in the following Table with units of million m^3:

Table 11.1 EWR for the Orange River obtained from the Orange River Replanning Study (ORRS)

Channel	Annual total	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920[1]	91.7	0.0	0.0	18.7	18.7	17.1	0.0	0.0	13.4	10.4	6.7	6.7	0.0
2142[2]	195.8	32.1	31.1	13.3	13.3	12.2	32.1	31.1	10.7	5.2	2.8	2.8	9.1

1 EWR components 1 and 2 combined represent the total EWR for maintenance at the river mouth.
2 EWR for drought situation (5%).

It has long been assumed that, though it is now understood that the current release for the environment is well below satisfactory, nothing can be done to modify it until the next scheme is built in the system. This would likely be a combination of Vioolsdrift Dam in the Lower Orange and Verbeeldingskraal Dam or other options in the Upper Orange with Polihali Dam in the Lesotho Highlands. However, what has changed in recent years is that, where these schemes were originally being considered for completion by 2019, they have now been pushed out and will likely only become operational by 2025. This is still eight years away.

Recent analyses as part of this study undertook to determine whether there was possibility an interim solution that could improve the current environmental release. A scenario was configured whereby the current ORRS “Orange River Mouth Requirement” was excluded from the simulation, and a modified environmental release was included. The release was based on the typical distribution required for the environment (i.e. following the natural flow pattern). The main objective of the analyses was that the environmental release would not to result in an impact on yield of the system in any way, i.e. no other users of the system should be at a deficit as a result of including an improved environmental release.

The outcome of the analyses showed that it is in fact possible to modify the current release without impacting the system yield, and to a greater benefit of the environmental state in the Lower Orange River. It is proposed that an interim EWR, i.e. the Preliminary Reserve, be implemented in the system, prior to the eventual Reserve and the related Classification process that will come online along with the new schemes.

The challenge now is to implement the interim Reserve. Further work is required in order to determine exactly how the variable EWR release pattern should look, and what will trigger the required releases.

11.2 PROPOSED IMPLEMENTATION METHODOLOGY

Very few practical examples exist in South Africa where a variable reserve release pattern is being released for, and is incorporated into the operation of a system. The Letaba system has a rudimentary process in order to improve flows into the Kruger National Park. While a similar process can be included in the Orange River system, it is anticipated that the operating procedure could be streamlined and improved on. The following steps would be required in order to undertake a study to implement the preliminary Reserve:

- **Step 1: Develop approach to determine an EWR release trigger which is usually natural flow, based on preceding weather conditions:** In order to determine what the EWR should be on a specified day, it is necessary to know what the natural flow would have been on that date, based on the preceding weather conditions (specifically rainfall) leading up to that date. A simplified approach should be developed in order to determine what the natural flow at the EWR sites should be, on any given day/month based on observed rainfall over a set time period. Existing calibrated rainfall runoff models can be used to determine the extent of the relationships that exist between rainfall and natural flow.

- **Step 2: Establishment of EWRs**. This has effectively been done as part of this study, whereby a Preliminary Reserve has been determined at EWR O5 (Sendelingsdrift).
- **Step 3: Develop Tool based on Step 1 approach:** This step should involve taking the information determined in step 1, and formalising it in a functional tool that will relate preceding observed rainfall to natural flow and then to the ecological requirement for a specified day.
- **Step 4: Produce Tool presentation techniques:** Once the EWR for a certain date has been determined, it should be compared with the observed actual flows at selected monitoring sites on a real-time basis. This step should develop the ability to do that, by building in the option to clearly present the real-time flows at the selected gauging points, and compare them graphically with what should be flowing, based on the set EWR. Alarm systems can be set up for occasions when the current flows remain lower or higher than the required flows for set time periods, prompting the end user of the tool to investigate the reasons for the differences.
- **Step 5: Establish operational links:** This step should develop a simple operational tool to use as a guide for releases that should be made at upstream dams in order to satisfy the EWR. EWR releases from the Vaal River system in support of the Orange River as well as spills from the Vaal River into the Orange need to be taken into account in this process. This is particularly important in the Orange River System due to the long lag times between dam releases and reaching the lower EWR sites.

The following figure presents the suggested approach to implement the preliminary EWR. Further work on defining the approach and linking it to annual operations is however required.

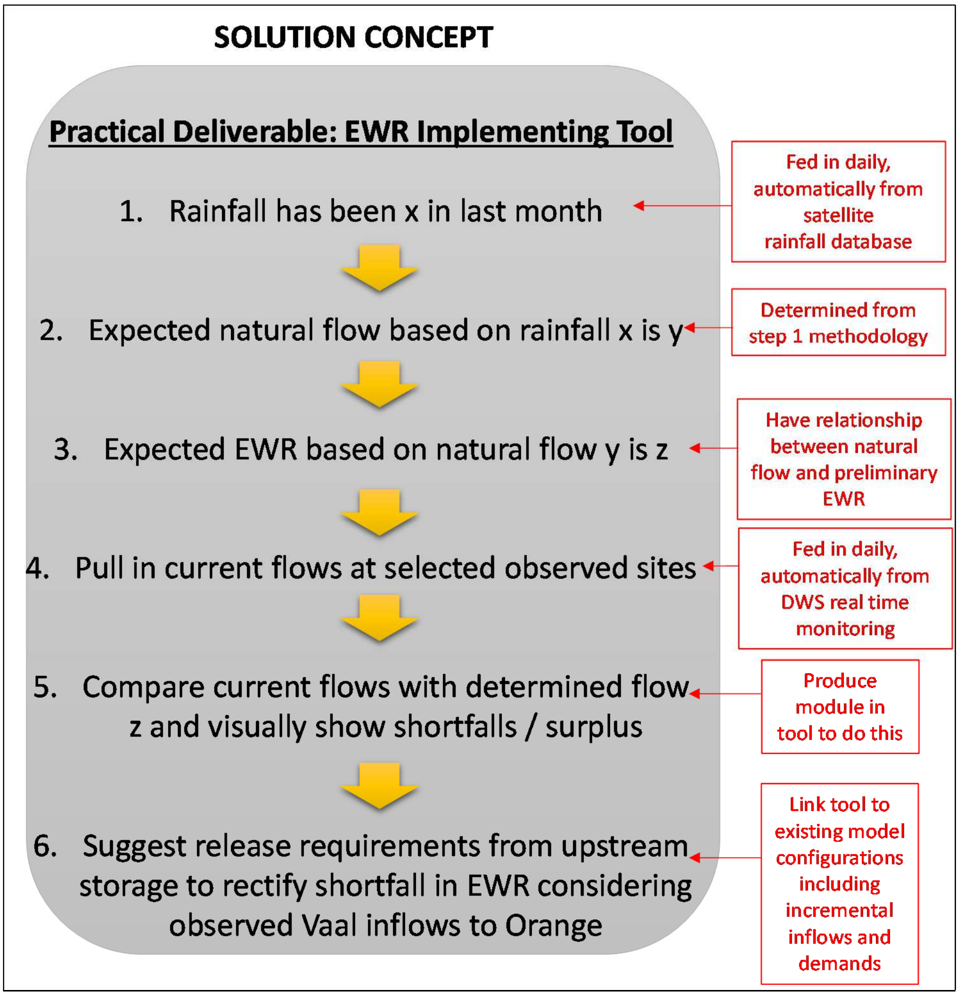

Figure 11.1 Suggested approach to implement the EWR

The implementation methodology is reliant on improved monitoring, especially of abstractions and return flows in the Lower Orange system as well as inflows from the Vaal River system. The following flow gauges already exist on the DWS real time monitoring system and can be used as guides as to whether or not the observed flows are as per EWR requirements and to manage the EWR releases:

- C9R002: Spills from Bloemhof Dam.
- C9H024: Vaal at Schmidsdrift.
- D7H005: Upington.
- D7H014: Orange at Neusberg.
- D8H014: Orange at Blouputs.
- D8H008: Orange at Pella Mission.
- D8H015: Orange at Sendelingsdrif.
- D8H007: Orange at Brandkaros.

Careful consideration needs to take place relating the required EWR releases with the other existing users. Alternate approaches to operation may be required and solutions to potential problems addressed. For example, the hydropower releases for Eskom should be considered and made in the context of the other users, and especially the environment. Impacts of releasing additional hydropower for Eskom in naturally low flow months should be determined.

12 REFERENCES

Anderson, M.D., Kolberg, H., Anderson, P.C., Dini, J., and Abrahams, A. 2003. Waterbird populations at the Orange River mouth from 1980-2001: A re-assessment of its Ramsar status.

Brown, A.C. 1959. The ecology of South African estuaries Part IX: notes on the estuary of the Orange River. Transactions of the Royal Society of South Africa 35: 463-473.

Cambray, J. 1984. Fish populations in the middle and lower Orange River, with special reference to the effect on stream regulation. Journal of the Limnological Society of South Africa, 10 (2):, 32-49.

CEMAGREF 1982. Etude des methodes biologiques quantitatives d'appreciation de la qualite des eaux. Rapport Division Qualité des Eaux Lyon - Agence Financiere de Bassin Rhône-Méditerranée- Corse. Pierre-Benite.

Cholnoky, B.J. 1968. Die Ökologie der Diatomeen in Binnengewässern. J Cramer, Lehre.

Chutter, F.M. 1996. Orange River: Aquatic invertebrates and their habitat requirements. 9pp + appendices. In: Orange River Planning Study: Orange River Environmental Task Group Field Trip Documentation 14-19 November 1995.

Dallas H.F., and Day J.A. 2004 The Effect of Water Quality Variables on Aquatic Ecosystems: A Review. WRC Report No TT224/04. Water Research Commission, Pretoria.

Day, J.H. 1981. Summaries of current knowledge of 43 estuaries in southern Africa. pp 251-329. In: Estuarine ecology with particular reference to southern Africa. (ed) Day, J.H. Cape Town: A.A. Balkema.

Department of Water Affairs (DWA), South Africa. 2009a. Operationalise the Reserve: Main Report. Prepared by Water for Africa. Compiled by D Louw and S Louw. RDM Report no. RDM/NAT/05/CON/0907.

Department of Water Affairs and Forestry (DWAF). 1995. South African Water Quality Guidelines for Coastal Marine Waters. Volume 1: Natural Environment. Pretoria.

Department of Water Affairs and Forestry (DWAF), South Africa. 1996a. South African Freshwater Quality Guidelines. Volume 7: Aquatic Ecosystems.

Department of Water Affairs and Forestry (DWAF), South Africa. 1996b. Orange River Development Project Replanning Study: Refinement of the instream flow requirements for the Orange River. Prepared by A Venter and M van Veelen from BKS (PTY) LTD. Report no. PD 00/00/6197.

Department of Water Affairs and Forestry (DWAF). 2008. Methods for determining the water quality component of the Ecological Reserve. Report prepared for Department of Water Affairs and Forestry, Pretoria, South Africa by P-A Scherman of Scherman Consulting.

Department of Water Affairs and Forestry (DWAF). 2009. Directorate Water Resource Planning Systems: Water Quality Planning. Orange River: Assessment of water quality data requirements for planning purposes. Water Quality Monitoring and Status Quo Assessment. Report No. 3 (P RSA D000/00/8009/1). ISBN No. 978-0-621-38690-5, Pretoria, South Africa.

Department of Water and Sanitation (DWS), South Africa. 2015. Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Volume 4: Estuary Resource Quality Objectives. Prepared by: Van Niekerk, Adams, Taljaard, Weerts. DWS Report: RDM/WMA11/00/CON/CLA/0615. September 2015.

Department of Water and Sanitation (DWS). South Africa. 2016a. River Eco-status Monitoring Programme. URL: https://www.dwa.gov.za/IWQS/rhp/default.aspx.

Department of Water and Sanitation (DWS), South Africa. 2016b. Determination of Ecological Water Requirements for Surface water (river, estuaries and wetlands) and Groundwater in the Lower Orange WMA. River EWR report. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. Authored by Louw D, Birkhead D, Koekemoer S, Mare M. DWS Report No: RDM/WMA06/00/CON/COMP/0216. August 2016.

Department of Water and Sanitation (DWS), South Africa, October 2016c. Determination of Ecological Water Requirements for Surface water (river, estuaries and wetlands) and Groundwater in the Lower Orange WMA. Groundwater EWR report. Prepared by: WSM Leshika Consulting (Pty) Ltd. Authored by K. Sami. DWS Report No: RDM/WMA06/00/CON/COMP/0416.

Department of Water and Sanitation (DWS), South Africa. 2017. Determination of Ecological Water Requirements for Surface water (River, Estuaries and Wetlands) and Groundwater in the Lower Orange WMA. Buffels, Swartlintjies, Spoeg, Groen and Sout Estuaries Ecological Water Requirement . Authored by CSIR: L van Niekerk, J Adams, SJ Lamberth, S Taljaard for Rivers for Africa. DWS Report No: RDM/WMA06/00/ CON/COMP/0316. February2017.

Edwards, D. 1983, A broad-scale structural classification of vegetation for practical purposes. Bothalia 14, 705 - 712.

Elzinga, C.L., Salzer, D.W., and Willoughby, J.W. 1998. Measuring and monitoring plant populations. BLM Technical Reference 1730-1, BLM/RS/ST-98/005+1730.

Fore, L.S. and Grafe, C. 2002. Using diatoms to assess the biological condition of large rivers in Idaho (U.S.A.). Freshwater Biology (2002) 47, 2015–2037.

Harrison, T.D. 1997. A preliminary survey of coastal river systems on the South African west coast, Orange River - Groot Berg, with particular reference to the fish fauna. Transactions of the Royal Society of South Africa 52: 277-321.

Hecky, R.E. and Kilham, P. 1973. Diatoms in alkaline, saline lakes: Ecology and geochemical implications. Limnology and oceanography 53 (Volume 18:1).

Kasperovičienė J. and Vaikutienė G. 2007. Long-term changes in diatom communities of phytoplankton and the surface sediments in the Curonian Lagoon (Lithuanian part) Transit. Waters Bull. 1:27-37.

Kelly M.G., Whitton B.A. 1995. The Trophic Diatom Index: a new index for monitoring eutrophication in rivers, Journal of Applied Phycology 7, 433- 444.

Kelly, M.G., Adams, C., Graves, A.C., Jamieson, J., Krokowski, J., Lyncett, E.B., Murry-Bligh, J., Pritchard, S. and Wilkins, C. 2001. The Trophic Diatom Index: A user's manual. Revised Edition. Environmental Agency Technical Report E2/TR2.

Kleynhans, C.J. 2007. Module D: Fish Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2) Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT 330/08.

Kleynhans, CJ and Louw, D. 2007. Reference frequency of occurrence of fish species in South Africa. Report produced for the Department of Water Affairs and Forestry (Resource Quality Services) and the Water Research Commission. Report produced for the Department of Water Affairs and Forestry (Resource Quality Services) and the Water Research Commission.

Kleynhans, C.J., Louw, M.D., Birkhead, A.L., Thirion, C., Deacon, A., Angliss, M., Maseti, P., Rodgers, S and Weston, B. 2009. On the way to implementation: Ecological reserve Monitoring. International Conference on Implementing Environmental Water Allocations (IEWA), Port Elizabeth – South Africa 23-26 February 2009.

Kleynhans, C.J. and Thirion, C. 2016. Fish Invertebrate Flow Habitat Assessment (FIFHA): A model for use in the monitoring of instream flow requirements at Ecological Water Requirement sites in South Africa. Beta version: Department of Water and Sanitation, RQIS.

Koekemoer, S. 2010. Support to Phase 2 of the ORASECOM Basin-Wide Integrated Water Resources Management Plan. Work Package 5: Assessment of Environmental Flow Requirements - Deliverable 12. Volume 3: Environmental Flow Requirements - Appendix B – Diatom Assessment of the Orange River Main Stem and Associated Tributaries. Prepared for WRP Consulting Engineers. Report 010/2011.

Lecointe, C., Coste, M., and Prygiel, J. 1993. "Omnidia": Software for taxonomy, calculation of diatom indices and inventories management. Hydrobiologia 269/270: 509-513.

Louw M.D. and S Koekemoer (Eds). 2010a. Deliverable 12: Volume 2: Support to Volume 1 in terms of monitoring: EcoSpecs and Thresholds of Potential Concern. Produced for WRP as part of Support to Phase II ORASECOM Basin Wide Integrated Water Resources Management Plan. Report 010/2011.

Louw M.D. and S Koekemoer (Eds). 2010b. Deliverable 12: Volume 1: Environmental Flow Requirements Produced for WRP as part of Support to Phase II ORASECOM Basin Wide Integrated Water Resources Management Plan. 193 pp.

Louw, M.D., Deacon, A., Koekemoer, S., Kotze, P., Mackenzie, J., Palmer, R., Rountree, M., Scherman, P-A., Van Niekerk, L., Taljaard, S., Huizinga, P., Theron, A., Snow, G., Adams, J., Wooldridge, T., Lamberth, S.J., Turpie, J. 2013a. Research project on environmental flow requirements of the Fish River and the Orange–Senqu River mouth: EFR monitoring programme. Prepared for the UNDP-GEF Orange-Senqu Strategic Action Programme (Atlas Project ID 71598). Technical Report 35.

Louw, M.D., Deacon, A., Koekemoer, S., Kotze, P., Mackenzie, J., Palmer, R., Rountree, M. and Scherman, P-A. 2013b. Research project on environmental flow requirements of the Fish River and the Orange–Senqu River mouth: River EFR assessment, Volume 1: Determination of lower Orange River EFR. Prepared for the UNDP-GEF Orange-Senqu Strategic Action Programme (Atlas Project ID 71598). Technical Report 29.

Louw, M.D., Deacon, A., Koekemoer, S., Kotze, P., Mackenzie, J., Palmer, R., Rountree, M. and Scherman, P-A. 2013c. Research project on environmental flow requirements of the Fish River and the Orange–Senqu River mouth: River EFR assessment, Volume 2: Lower Orange River EFR, supporting information. Prepared for the UNDP-GEF Orange-Senqu Strategic Action Programme (Atlas Project ID 71598). Technical Report 30. - Appendix C.

Luís, A.T., Teixeira, P., Almeida, S.F.P., Ector, L., Matos, J.X. and Ferreira da Silva, A. 2008. Impact of Acid Mine Drainage (AMD) on Water Quality, Stream Sediments and Periphytic Diatom Communities in the Surrounding Streams of Aljustrel Mining Area (Portugal). Water Air Soil Pollution. DOI 10.1007/s11270-008-9900-z.

Morales, E.A. 2002. Studies in selected fragilarioid diatoms of potential indicator value from Florida (USA) with notes on the genus Opephora PETIT (Bacillariophyceae). Limnologica 32: 102–113.

Morant, P.D. and O'Callaghan, M. 1990. Some observations on the impact of the March 1988 flood on the biota of the Orange River mouth. Transactions of the Royal Society of South Africa 47: 295-305.

Orange-Senqu River Commission (ORASECOM). 2011a. Baseline monitoring of Aquatic Ecosystem Health in the Orange-Senqu River Basin: Final Report: Part 1 – Main Report. Southern African Development Community: Water Sector Support Unit – Gaborone. European Development Fund. African Transboundary River Basin Support Programme. Global Financial Commitment No. 9 ACP RPR 53. Orange Senqu River Commission Report No. 015/2011.

Orange-Senqu River Commission (ORASECOM). 2011b. Baseline monitoring of Aquatic Ecosystem Health in the Orange-Senqu River Basin: Final Report: Part 2 – Summary Report. Southern African Development Community: Water Sector Support Unit – Gaborone. European Development Fund. African Transboundary River Basin Support Programme. Global Financial Commitment No. 9 ACP RPR 53. Orange Senqu River Commission Report No. 014/2011.

Orange-Senqu River Commission (ORASECOM). 2015. ORASECOM Joint Basin Survey 2 (JBS 2): Final Report – Water Resources Quality Monitoring. Report prepared by GroundTruth Water, Wetlands and Environmental Engineering in association with The Biodiversity Company. Report ORASECOM/001/2015.

Palmer, R.W. 2004. Impacts on aquatic ecosystems. Environmental impact assessment and compilation of an environmental management plan for the proposed Sendlingdrif Irrigation Project. Specialist report prepared for Enviro Solutions. Windhoek.

Philibert, A., Gell, P., Newall, P., Chessman, B. and Bate, N. 2006. Development of diatom-based tools for assessing stream water quality in south-eastern Australia: assessment of environmental transfer functions. Hydrobiologia 572: 103–114.

Rogers, K.H. and Bestbier, R. 1997. Development of a protocol for the definition of the desired state of riverine systems in South Africa. Department of Environmental Affairs and Tourism, Pretoria.

Ryan, P.G. and Cooper, J. 1985. Waders (Charadrii) and other coastal birds of the northwestern Cape Province, South Africa. Bontebok 4: 1-8.

Seaman, M.T. and Van As, J.G. 1998. The environmental status of the Orange River mouth as reflected by the fish community. WRC Report No. 505/1/98: 73 pp.

Simmons, R.E. 1994. Namibia/Namibie. In: Taylor, V. & Rose, P. (eds). African Waterfowl Census 1994. Slimbridge: The International Waterfowl and Wetlands Research Bureau.

Simmons, R.E. 1995. Namibia/Namibie. In: Taylor, V. & Dodman, T. (eds). African Waterfowl Census 1995. Slimbridge: The International Waterfowl and Wetlands Research Bureau.

Spaulding, S., and Edlund, M. 2008. *Cyclostephanos*. In Diatoms of the United States. Retrieved April 10, 2017, from http://westerndiatoms.colorado.edu/taxa/genus/Cyclostephanos.

Taylor, J.C., Harding, W.R. and Archibald, C.G.M. 2007a. A methods manual for the collection, preparation and analysis of diatom samples. Water Research Commission Report TT281/07. Water Research Commission. Pretoria.

Taylor, J.C., Harding, W.R. and Archibald, C.G.M. 2007b. An illustrated guide to some common diatom species from South Africa. Water Research Commission Report TT282/07. Water Research Commission. Pretoria.

Taylor, P.B., Navarro, R.A., Wren-Sargent, M., Harrison, J.A. & Kieswetter, S.L. 1999. TOTAL CWAC Report: Coordinated Waterbird Counts in South Africa, 1992-1997. Cape Town: Avian Demography Unit.

Teply, M. and Bahls, L. 2006. Interpretation of Periphyton Samples for Montana Streams - Middle Rockies Ecoregion. Prepared for the Montana Department of Environmental Quality. Water Quality Monitoring Section. Rosie Sada. Project Manager.1520 E 6th Avenue. Helena, MT 59620.

Thirion, C. 2007. Module E: Macroinvertebrate Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT330/08.

UNEP/Nairobi Convention Secretariat and CSIR. 2009. Guidelines for the Establishment of Environmental Quality Objectives and Targets in the Coastal Zone of the Western Indian Ocean (WIO) Region, UNEP, Nairobi, Kenya, 169p.

United States Environmental Protection Agency (USEPA). 1998. Lake and Reservoir Bioassessment and Biocriteria, Technical Guidance Document Nr. EPA-841-B-98-007. http://www.epa.gov/owow/monitoring/tech/lakes.html.

Van Niekerk, L., Taljaard, S., Huizinga, P., Theron, A., Snow, G., Adams, J., Wooldridge, T., Lamberth, S.J., and Turpie, J. 2013. Research project on environmental flow requirements of the Fish River and the Orange–Senqu River mouth: Estuary and Marine EFR Assessment, Volume 1: Determination of Orange Estuary. Prepared for the UNDP-GEF Orange-Senqu Strategic Action Programme (Atlas Project ID 71598). Technical Report 32.

Weitzel, R.L. 1979. Methods and measurement of periphyton communities: a review. Volume 690 of Special technical publication, American Society for Testing and Materials. 183pp.

Williams, A.J. 1986. Wetland birds at the Orange River mouth and their conservation significance. Bontebok 5: 17-23.

13 APPENDIX A: EWR O2 (BOEGOEBERG): ECOSPECS AND TPCs

Scenarios were not evaluated at Boegoeberg Dam due to the limited capacity to provide operation in the system. As such, EWR O2 is not a key site for monitoring, however, the data is provided. The EcoSpecs and TPCs as generated before and documented in Louw and Koekemoer (2010a) are provided below.

A summary of the site EcoClassification results is provided below (DWS, 2016b). The PES will be the REC as the improvement for vegetation will require flow regulation from the Boegoeberg Dam which is not possible.

Table 13.1 EWR O2: EcoClassification results

<table>
<tr><th colspan="5">EWR O2 (BOEGOEBERG)</th></tr>
<tr><td rowspan="13">EIS[1]: HIGH
Highest scoring metrics are instream and riparian rare /endangered biota, unique riparian biota, instream biota intolerant to flow, taxon richness of riparian biota, diversity of riparian habitat types, critical riparian habitat, refugia, and migration corridor.

PES: C
Loss of large flood frequency, agricultural return flows, higher low flows than natural in the dry season, drought and dry periods, decreased low flows at other times, therelease of sediment, presence of alien fish species and barrier effect of dams.

REC: B/C
Instream improvement was not possible due to constraints and no EWR was set for the REC.</td><td>Driver Components</td><td>PES</td><td>TREND</td><td>REC</td></tr>
<tr><td>IHI HYDROLOGY</td><td>E</td><td></td><td></td></tr>
<tr><td>WATER QUALITY</td><td>C</td><td></td><td>C</td></tr>
<tr><td>GEOMORPHOLOGY</td><td>C</td><td>0</td><td>C</td></tr>
<tr><td>Response Components</td><td>PES</td><td>TREND</td><td>REC</td></tr>
<tr><td>FISH</td><td>C</td><td>0</td><td>C</td></tr>
<tr><td>MACRO INVERTEBRATES</td><td>C</td><td>0</td><td>C</td></tr>
<tr><td>INSTREAM</td><td>C</td><td>0</td><td>C</td></tr>
<tr><td>RIPARIAN VEGETATION</td><td>B</td><td>0</td><td>A/B</td></tr>
<tr><td>ECOSTATUS</td><td>C</td><td>0</td><td>B/C</td></tr>
<tr><td>EIS</td><td colspan="3">HIGH</td></tr>
</table>

1 Ecological Importance and Sensitivity

EcoSpecs and TPCs for EWR O2 are provided for the different components in Section 13.1 to 13.5.

13.1 WATER QUALITY

The EcoSpecs and TPCs for water quality (Table 13.2) are based on the PES and PERC of a C.

Table 13.2 EWR O2: Water quality EcoSpecs and TPCs (PES and REC: C)

River: Orange		PES and PERC: C Category
Water quality metrics	**EcoSpecs**	**TPC**
Inorganic salts(*)		
$MgSO_4$	The 95th percentile of the data must be ≤ 16 mg/L.	The 95th percentile of the data is 13 – 16 mg/L.
Na_2SO_4	The 95th percentile of the data must be ≤ 20 mg/L.	The 95th percentile of the data is 16 – 20 mg/L.
$MgCl_2$	The 95th percentile of the data must be ≤ 15 mg/L.	The 95th percentile of the data is 12 – 15 mg/L.
$CaCl_2$	The 95th percentile of the data must be ≤ 21 mg/L.	The 95th percentile of the data is 17 – 21 mg/L.
NaCl	The 95th percentile of the data must be ≤ 45 mg/L.	The 95th percentile of the data is 36 – 45 mg/L.
$CaSO_4$	The 95th percentile of the data must be ≤	The 95th percentile of the data is 280 – 351

River: Orange		PES and PERC: C Category
Water quality metrics	**EcoSpecs**	**TPC**
	351 mg/L.	mg/L.
Physical variables		
Electrical Conductivity	The 95th percentile of the data must be ≤ 55 mS/m.	The 95th percentile of the data is 44 – 55 mS/m.
pH	The 5th percentile of the data must range from 6.5 to 8.0, and the 95th percentile from 8.0 to 8.8	The 5th percentile of the data is <6.7 and >7.8, and the 95th percentile is <8.2 and >8.6
Temperature	Moderate to large changes to temperature regime occur frequently, with fluctuations of 2 to 4°C.	Rely on biotic response data to evaluate whether the TPC for temperature is being reached. Most highly temperature sensitive species are in lower abundances and frequency of occurrence than expected for reference.
Dissolved oxygen	The 5th percentile of the data must be ≥6.5 mg/L. Some concerns about dissolved oxygen, with only some oxygen sensitive species present.	The 5th percentile of the data is <6.7 mg/L.
Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.	Silting of habitats. Check biotic response for habitat-related changes.
Nutrients		
Total Inorganic Nitrogen (TIN-N)	The 50th percentile of the data must be ≤ 0.25 mg/L.	The 50th percentile of the data must be 0.2 - 0.25 mg/L.
PO_4-P	The 50th percentile of the data must be ≤ 0.025 mg/L.	The 50th percentile of the data must be 0.02 - 0.025 mg/L.
Response variables		
Chl-*a* phytoplankton	The 50th percentile of the data must be ≤ 20 mg/L(#).	The 50th percentile of the data must be 16 - 20 µg/L(#).
Chl-*a* periphyton	The 50th percentile of the data must be ≤ 21 mg/m^2 (#).	The 50th percentile of the data must be 17 - 21 mg/m^2(#).
Toxics		
Toxics	The 95th percentile of the data must be within the Chronic Effects Value (CEV) as stated in DWAF (1996a)(##).	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996a).

(*) To be generated using TEACHA when the TPC for Electrical Conductivity is exceeded or salt pollution is expected. Should the TPC for any integrated salt be exceeded, 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.
(#) Low confidence. EcoSpec and TPC boundaries may need adjusting as data become available.
(##) Although category boundaries exist in the Water quality Reserve manual (DWAF, 2008) for a number of toxicants, adherence to the CEV (DWAF, 1996a) is recommended for the present state. Data collection and testing will need to be undertaken to assess the suitability of these objectives.

Land-use is agricultural, resulting in some toxicant and nutrient loading. The upstream dams still have some impact in terms of temperature.

13.2 DIATOMS

Site specific diatom data were available from sample collection during 2005, and 2008 – 2010 across the reach from Boegoeberg Dam to Augrabies, along with measured *in situ* water quality measurements.

The biological water quality fluctuated between a B/C and C/D EC during 2005, 2008 – 2009, and 2010 and it was evident that there was a gradual deterioration within the reach. Nutrient levels were elevated throughout the reach and agriculture seemed to be the major impact in this reach. Chloride concentrations were problematic during July 2005. Although elevated at times, organic pollution did not seem to be a major problem in this reach. Nutrients were elevated for all sampling years indicating continuous impact, while salinity was problematic at times.

A summary of diatom data collected at EWR O2 is provided in Table 13.3. The EcoSpecs and TPCs for this reach were set at a C Category and provided in Table 13.4.

Table 13.3 EWR O2: Summary of available diatom results

Sample date	SPI	PTV (%)	EC
May 2008	10.6	5.3	C/D
August 2009	12.9	9	C
June 2010	14.8	1.5	B/C
June 2011	13.4	6.3	C

Table 13.4 EWR O2: Diatom EcoSpecs and TPCs (C PES)

Metric and associated indicator group/species	Indicator species information	EcoSpec	TPC	General comment
SPI score	N/a	12 – 14	11 - 12	The diatom-based water quality for this site should fall within a C Category. If thresholds are exceeded during consecutive low and high flow water quality deterioration should be deemed as serious and impacts should be substantiated with water quality analysis and available data.
PTVs (%)	N/a	<10	>10	PTV scores were generally low indicating that organic pollution levels are generally low. If thresholds are exceeded during consecutive low and high flow this metric should be flagged.
Valve deformities (%)	N/a	<2	>2	A check should be done for valve deformities with every count as this is indicative of metal contamination. If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken to determine the presence of metal toxicity.
Oxygenation				
Achnathidium spp. abundance (% of total count)	Are associated with elevated flows. The genus generally prefers good water quality with high oxygenation rates (Taylor *et al*., 2007b). Species that should be included in count: *A. minutissima, A. biasolettianum, A. pyrenaicum* and *A. rivulare.*	>2	<2	During high/elevated flow this genus must be present and is an important indicator of system recovery. Species should not be absent in more than one high flow sample. If absent, water quality analysis should be undertaken.
Encyonopsis spp. abundance (% of total count)	Cosmopolitan species found in calcareous waters with a moderate electrolyte content. Requires an oxygen rich environment (Taylor *et al*., 2007b). Species that should be included in count: *E. minuta, E. microcephala,* and *E. leei* var. *sinensis.*	>5	<5	This genus should be present in high and low flow samples. They are indicators of good to high oxygenation rates, and are sensitive to water quality deterioration. If absent during three consecutive samples, water quality analysis should be undertaken.
Nutrients				
Cocconeis spp. abundance (% of total count)	The genus *Cocconeis* has a broad ecological range and is found in most running waters except where nutrients are low or acidic conditions prevail (Taylor *et al*., 2007b). This genus is tolerant of moderate organic pollution and also extends into brackish waters. It is abundant on rocks, but is also found on other surfaces such as	<5	>5	If thresholds are exceeded during consecutive low and high flow this variable should be flagged.

Metric and associated indicator group/species	Indicator species information	EcoSpec	TPC	General comment
	filamentous algae and macrophytes (Kelly *et al*., 2001). According to Fore and Grafe (2002), *C. placentula* prefer alkaline, eutrophic conditions. Species that should be included in count: *C. placentula, C. pediculus* and *C. placentula* var. *euglypta.*			
Nitzschia species abundance (% of total count)	Associated with water bodies that have readily available nutrients. Species that should be included in count: *Nitzschia* species with a preference for moderate to high nutrient levels as well as species in girdle view.	<5	>5	
Organics				
Amphora pediculus abundance (% of total count)	A cosmopolitan species found in waters with a moderate electrolyte content and tolerating critical levels of pollution (Taylor *et al*., 2007b).	<5	>5	If thresholds are exceeded during consecutive low and high flow this variable should be flagged.
Gomphonema parvulum abundance (% of total count)	Indicates organic enrichment, which is usually associated with sedimentation, both organic and inorganic sediment (Teply and Bahls, 2006).	<3	>3	
Eolimna spp. abundance (% of total count)	Pioneer species ('r-strategists') that colonise bare surfaces and occur in greater abundance with the onset of organic pollution as these species are pioneer species while the community would shift to a dominance of *Sellaphora seminulum* as the community adjusts to the organic pollution levels. Species that should be included in count: *E. minima* and *E. subminuscula*.	<3	>3	
Salinity				
Cyclostephanos spp. abundance (% of total count)	In North America, smaller species of *Cyclostephanos* often dominate the plankton flora during spring and summer in nutrient rich lakes and rivers. Many of the species are tolerant of elevated levels of total dissolved solids and are present in highly calcareous or saline waters (Spaulding and Edlund, 2008). Species that should be included in count: *C. dubius* and *C. invisitatus.*	<10	>10	If thresholds are exceeded during consecutive low and high flow this metric should be flagged.
Stephanodiscus spp. abundance (% of total count)	Occur in waters with elevated electrolyte content. Species that should be included in count: *S. agassizensis*, *S. minutulus* and *S. hantzschii.*	<5	>5	
Turbidity				
Stephanodiscus agassizensis abundance (% of total count)	A planktonic species found in eutrophic rivers and lakes with an elevated electrolyte concentration and turbidity (Taylor *et a*l., 2007b)	<2.5	>2.5	If thresholds are exceeded during consecutive low and high flow this metric should be flagged.

13.3 RIPARIAN VEGETATION

The EcoSpecs and TPCs for riparian vegetation (Table 13.5) are based on the PES and PERC of a B.

Table 13.5 EWR O2: Riparian vegetation EcoSpecs and TPCs (PES and PERC: B)

Component	EcoSpec (PES and PERC)	TPC (PES and PERC)
Riparian zone		
Alien Invasion (perennial aliens)	Maintain alien species cover below 10%.	An increase in alien species cover above 10%.
Marginal Zone		
Terrestrialisation	Maintain an absence of terrestrial species.	An occurrence of terrestrial species.
Indigenous Riparian Woody Cover	Maintain riparian woody species cover between 5% and 60%.	An increase in riparian woody species cover above 60% OR a decrease below 5%.
P. australis (reed) cover	Maintain reed cover less than 40%.	An increase in reed cover above 40%.
Lower Zone		
Terrestrialisation	Maintain an absence of terrestrial species.	An occurrence of terrestrial species.
Indigenous Riparian Woody Cover	Maintain riparian woody species cover between 5% and 50%.	An increase in riparian woody species cover above 50% OR a decrease below 5%.
P. australis (reed) cover	Maintain reed cover less than 40%.	An increase in reed cover above 40%.
Upper Zone		
Terrestrialisation	Maintain terrestrial species cover between 10 and 15%.	An increase above 15% of terrestrial species cover.
Indigenous Riparian Woody Cover	Maintain riparian woody species cover between 10% and 50%.	An increase in riparian woody species cover above 50% OR a decrease below 10%.
Macro Channel Bank (MCB)		
Terrestrialisation	Maintain terrestrial species cover between 10 and 15%.	An increase above 15% of terrestrial species cover.
Indigenous Riparian Woody Cover	Maintain riparian woody species cover between 30% and 60%.	An increase in riparian woody species cover above 60% OR a decrease below 30%.

13.4 FISH

EcoSpecs and TPCs are provided for FRAI data in Table 13.6. The spatial FROC of EWR O2 is provided in Table 13.7 and indicates the FROC under reference, PES and PERC conditions as well as TPCs for baseline (PES) conditions.

Table 13.6 EWR O2: Fish EcoSpecs and TPCs (PES and PERC: C)

Indicator	PES & PERC (C)				
	EWR Site			Reach	
	EcoSpecs	TPC (Biotic)	TPC (Habitat)	Indicator Spp.	TPC (Biotic)
Rank 1. Species richness					
All indigenous species	**Eight (8)** of the expected (under reference conditions) 11 indigenous fish species were sampled during the baseline (EWR) surveys.	**Less than (<) 6** fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features.	All indigenous species	Baseline (PES) FRAI score of 67% (C) calculated for the reach. Any decreased FROC in reach of especially ASCL, BAEN, BKIM and BTRI (refer to sheet 5-FROC: Table 2) OR FRAI scores decreasing below 62.02% (Category C/D).
Rank 2. Relative abundance					
N/A	During the baseline (EWR) surveys fish were sampled at **2.35** ind/min[1] using a SAMUS electrofisher during wading. Relative abundance was very low.	Relative abundance of **less than (<) 2** ind/min sampled at the site (during same season as baseline data) when habitat can be sampled efficiently and using comparable method.	N/A	N/A	N/A
Rank 7. Alien fish species					
Any alien/ introduced spp.	Any alien/introduced spp.	Three alien species, namely CCAR, GAFF and CIDE sampled at site during baseline EWR survey.	Presence of any additional alien/introduced species.	N/A	Any alien/introduced spp.
Rank 3: FD habitats, substrate, flow dependant spp. (flow alteration), SD habitats and water column					
BAEN LCAP	The two indicator species of this metric group, BAEN and LCAP, were sampled at the site during the baseline EWR surveys. BAEN was relatively scarce (0.03 ind/min) while LCAP was more abundant at 0.8 ind/min.	BAEN and/or LCAP absent during any survey **OR** present at relative abundance of <0.03 ind/min for BAEN or <0.5 ind/min for LCAP.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates. Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality,	BAEN LCAP	Any decreased FROC in reach of BAEN and LCAP (refer to sheet 5-FROC, column F: Table 2).

Indicator	PES & PERC (C)				
	EWR Site			Reach	
	EcoSpecs	TPC (Biotic)	TPC (Habitat)	Indicator Spp.	TPC (Biotic)
			sedimentation of pools). Reduction in suitability of water column (i.e. increased sedimentation of pools).		
Rank 4: FS habitats					
BAEN ASCL	The two indicator species of this metric group, BAEN and ASCL were sampled at the site during the baseline EWR surveys. Both these species were scarce at the site, with BAEN being present at relative abundance of 0.03 ind/min and ASCL at 0.02 ind/min.	BAEN and/or ASCL absent during any survey **OR** present at relative abundance of <0.03 ind/min for BAEN and <0.02 ind/min for ASCL.	Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows).	BAEN ASCL	Any decreased FROC in reach of BAEN and ASCL (refer to sheet 5-FROC, column F: Table 2).
Rank 3: Water quality intolerance					
BAEN LCAP	In the absence of BKIM (not sampled at site during baseline EWR surveys) the two indicator species of this metric group is BAEN and LCAP. Both were sampled at the site during the baseline EWR surveys. BAEN was relatively scarce (0.03 ind/min) while LCAP was more abundant at 0.8 ind/min.	BAEN and/or LCAP absent during any survey **OR** present at relative abundance of <0.03 ind/min for BAEN or <0.5 ind/min for LCAP.	Decreased water quality.	BKIM	Any decreased FROC in reach of BKIM (refer to sheet 5-FROC, column F: Table 2).
Rank 6: SS habitats, overhanging vegetation					
BPAU PPHI	The most appropriate indicators of this metric is PPHI and BPAU. PPHI was present at relative abundance of 0.03 ind/min and BPAU at 0.02 ind/min.	PPHI and/or BPAU absent during any survey **OR** present at relative abundance of <0.03 ind/min for PPHI and <0.02 ind/min for BPAU.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats). Significant change in overhanging vegetation habitats.	BPAU PPHI	Any decreased FROC in reach of BPAU and PPHI (refer to sheet 5-FROC, column F: Table 2).

Indicator	PES & PERC (C)				
	EWR Site			Reach	
	EcoSpecs	TPC (Biotic)	TPC (Habitat)	Indicator Spp.	TPC (Biotic)
Rank 5: Undercut banks					
ASCL PPHI	The most appropriate indicators of this metric is PPHI and ASCL PPHI was present at relative abundance of 0.03 ind/min and ASCL at 0.02 ind/min.	PPHI and/or ASCL absent during any survey **OR** present at relative abundance of <0.03 ind/min for PPHI and <0.02 ind/min for ASCL.	Significant change in undercut bank habitats.	ASCL PPHI	Decreased FROC in reach of ASCL and PPHI (refer to sheet 5-FROC, column F: Table 2).
Rank 6: Instream vegetation					
BPAU TSPA	The most appropriate indicators of this metric are TSPA and BPAU. TSPA was present at relative abundance of 0.08 ind/min and BPAU at 0.02 ind/min.	TSPA and/or BPAU absent during any survey **OR** present at relative abundance of <0.08 ind/min for TSPA and <0.02 ind/min for BPAU.	Significant change in overhanging vegetation habitats.	BPAU TSPA	Any decreased FROC in reach of BPAU and TSPA (refer to sheet 5-FROC, column F: Table 2).

1 Individual per minute.

Table 13.7 EWR O2: Spatial FROC under reference, PES and PERC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC		
		Reference (A)	PES & PERC (C)	
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC
Indigenous species				
ASCL	*Austroglanis sclateri* (Boulenger, 1901)	3	2	1
BAEN*	*Labeobarbus aeneus* (Burchell, 1822)	5	4	3
BANO	*Barbus Anoplus* (Weber, 1897)	2	0.5	0
BKIM	*Labeobarbus kimberleyensis* (Gilchrist & Thompson, 1913)	3	1.5	0.5
BPAU*	*Barbus paludinosus* (Peters, 1852)	4	3.5	2.5
BTRI*	*Barbus trimaculatus* (Peters, 1852)	3	2.5	1.5
CGAR*	*Clarias gariepinus* (Burchell, 1822)	3	2.5	1.5
LCAP*	*Labeo capensis* (Smith, 1841)	5	4.5	3.5
LUMB	*Labeo umbratus* (Smith, 1841)	3	0.5	-0.5
PPHI*	*Pseudocrenilabrus philander* (Weber, 1897)	3	2.5	1.5
TSPA*	*Tilapia sparrmanii* (Smith, 1840)	2	1.5	0.5
Introduced species				
CCAR*	*Cyprinus carpio* (Linnaeus, 1758)			
GAFF*	*Gambusia affinis* (Baird & Girard, 1853)			
CIDE*	*Ctenopharyngodon idella* (Valenciennes, 1844)			

* Sampled at EWR site during baseline survey (June 2010).

13.5 MACROINVERTEBRATES

13.5.1 SASS data

Available SASS5 data collected at or near Site EWR O2 are summarised in Table 13.8.

Table 13.8 EWR O2: Available SASS 5 data

Site	Date	SASS Score	ASPT	No. of Taxa	Reference
D7ORAN-PRIES	12-Oct-2004	62	5.2	12	Ramogale Sekwele (River Health Database)
D7ORAN-PRIES	8-Mar-2005	118	5.9	20	Ramogale Sekwele (River Health Database)
D7ORAN-GROBL	8-Mar-2005	91	5.7	16	Ramogale Sekwele (River Health Database)
D7ORAN-GROBL	24-Nov-2005	106	6.2	17	Ramogale Sekwele (River Health Database)
D7ORAN-PRIES	25-Nov-2005	115	5.2	22	Ramogale Sekwele (River Health Database)
EWR O2	31-May-2010	116	5.8	20	This study

13.5.2 Indicator taxa

Baetidae (>2 spp.), Leptophlebiidae, Tricorythidae, Atyidae Hydropsychidae and Gomphidae were selected as monitoring indicators for EWR O2. Table 13.9 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 13.9 EWR O2: Habitat preference of macroinvertebrate indicator taxa

Habitat metrics	Baetidae	Leptophlebiidae	Tricorythidae	Atyidae	Hydropsy-chidae	Gomphidae
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)						
Moderate (SASS 7 - 10)	10	9	9	8		
Low (SASS 4 - 6)					6	6

13.5.3 EcoSpecs and TPCs

EcoSpecs and TPCs for the PES and PERC at EWR O2 are provided in Table 13.10.

Table 13.10 EWR O2: Macroinvertebrate EcoSpecs and TPCs (PES and PERC: C)

EcoSpecs	TPCs
SASS5 Score between 143 and 161.	SASS5 Score <150.
ASPT between 5.9 and 6.3.	ASPT <6.1.
MIRAI Score between 60% and 79%.	MIRAI Score <63%.
At least 50% indicator taxa present.	Three or more Indicator Taxa absent.
Indicator Taxa	
Baetidae >2 spp.	Baetidae <2 spp. on any one survey.
Leptophlebiidae present.	Leptophlebiidae absent on two or more consecutive surveys.
Tricorythidae present (except winter).	Tricorythidae absent on two or more consecutive surveys.
Atyidae present.	Atyidae absent on two or more consecutive surveys.
Hydropsychidae present.	Hydropsychidae absent on two or more consecutive surveys.
Gomphidae present.	Gomphidae absent on two or more consecutive surveys.

14 APPENDIX B: COMMENTS REGISTER

Section	Report statement	Comments	Changes made?	Author comment
All editorial comments suggested by reviewers were incorporated in report.				
Front pages	Report Title	Could this be written in full in a report Title: Ecological Specifications.	Yes	
Exec summary	D54B in the vicinity of Carnarvon where insufficient data is available. Monitoring for arsenic is also recommended.	How was it arrived at which parameter(s) to monitor? Short explanation please, just to make the reader understand why these were selected since there's no Chapter on Approach and Methods for Groundwater.	Yes	
Table 10.1		It would be useful to have an explanation in this section as to how Groundwater Dependency was calculated since there's no Chapter on Approach and Methods for groundwater based on use data from WARMS only or other possible sources were explored Are the suggested parameters the only ones to monitor or they are in addition to the normal parameters of the DWS GWQuality monitoring programme?	Yes	To identify stressed areas in terms of water quantity, data on domestic groundwater use was collected from the All Towns strategy reports, and the Lower Orange ISP. Where no data was available from the All Towns studies, the ISP data was used. Schedule 1 water use was determined from the Census 2011 data water sources. The combined domestic water use from formal groundwater schemes and schedule 1 water users divided by total domestic water use determined the Groundwater Depenency. Livestock water use was obtained from GRAII and Irrigation, Mining and industrial water use from WARMS to obtain a total water use. The total water use relative to recharge is the stress index. To determine water quality monitoring requirements, trace groundwater quality constituents in the Department of Water Affairs and Sanition ZQM database were analysed. Severeal chemical parameters which sometimes exceed potable standards were identified, these being Arsenic and Molybdendum.
		This question is for all the GRUs where mining takes place: Have the mines in the area not been monitoring for long term or this excludes private monitoring?	No	Water level data in the report excludes private data not available in the public domain.
		Does empty mean no need to monitor	Yes	A blank in monitoring requrements means no additional

Section	Report statement	Comments	Changes made?	Author comment
		quality OR not enough data to conclude on what to monitor?		monitoring is required as no water quality problem exists in the availbale data and the host geology does not suggest any additional monitoring is required.
General comments				
		Overall it seems well written but there are some editing required to sort out inconstancies with respect to the numbering of sites, words missing etc. Perhaps a map of the sites or a description of the site localities should be included in the executive summary and also earlier in the document.	Yes	
		It is important to remember that RQOs and EcoSpecs must be measurable and should be easily included in existing monitoring programmes. Generally speaking this has been taken into consideration but the concern is that some of the EcoSpecs particularly relating to the Physico-chemical aspects may require more information than is likely to be readily available.	No	EcoSpecs are provided at priority sites for all water quality variables, as required by Reserve methods, thereby ensuring that an objective is available for any variable that may need to be monitored for ecological purposes. Methods for measuring the variables are all available, although all variables may not be part of an existing monitoring programme. These are issues that would be addressed during the Classification and RQO process, which would also look at the implementation of monitoring. Variables to be monitored as RQOs are therefore selected in a secondary process during Classification/RQO, and is guided by a process including the identification of priority water quality role players (e.g. ecology and other users), driving variables, existing monitoring programmes etc. RQOs finally gazetted as immediately applicable, are then selected through a further level of selection. Note that it is not considered ethical to not include problem variables (e.g. pesticides or turbidity) simply because they cannot be easily monitored or a monitoring programme does not exist, as there has to be some system of initiating monitoring if a problem has been identified. This would however be identified as a long-term process. Presumably the latter point re: monitoring programmes would not be relevant to the EWR sites and their EcoSpecs anyway, as they would be priority monitoring sites.

Section	Report statement	Comments	Changes made?	Author comment
		The concerned centering on the inclusion of CPUE as part of the Fish EcoSpecs.	Yes	It is acknowledged that use of "abundance" (measured in Catch Per Unit Effort) as a metric in the setting of EcoSpecs may require further verification and testing. It is however important (as described in literature) that in a low fish species diversity ecosystem (typical of cold water systems), the use of fish species diversity (presence/absence) alone may not be an adequate measure of change, since the range of species may not adequately represent varying intolerances to a different stressors. It is also a known fact that a change in abundance is often the first indication of a change in ecosystem health and hence a more conservative approach to use as an early warning system (rather than waiting for a species to disappear before reacting). The measure of abundance can be variable an is dependent on especially sampling method and season. It is however stated in the EcoSpecs that monitoring should ideally be applied during similar seasons and using similar sampling methods, and that these values need to be verified and where applicable amended over time.
		It seems as if no recent biological information was used. DWS and NC Environmental Affairs have been conducting biomonitoring in the Lower Orange for a number of years and none of these data or the data from the 2015 ORASECOM study has been included.		The water quality specialists did take the recent ORASECOM study into account during the revision of the EcoSpecs. However, the EWR data is the baseline from which EcoSpecs are derived. Subsequently monitoring programmes are supposed to use this information to determine if the EcoSpecs and TPCs are correct and provide additional information if the parameters should change. A similar comment was made during the Inception phase of the project and the response provided in the Inception report is provided below: The EcoStatus models and results from the baseline EcoStatus (as it was done at Level IV). The EWRs were set for this baseline. This cannot change. Monitoring information can only indicate whether there are changes from the baseline (doubtful as there have been no operational changes in the river during the las

Section	Report statement	Comments	Changes made?	Author comment
				2 years (last surveys were in 2013 at estuary and EWR O5). Furthermore, JBS2 did not undertake surveys at the EWR sites, neither did they use the results generated during the EWR studies as a baseline. . The initial REMP surveys also follow from the EWR baseline and one of the main purposes are to determine change from the baseline. Lastly, none of the data has been worked into EcoStatus model to determine results at the Level IV EcoClassification method, neither has the full EcoClassification procedures been provided. Therefore, although the information is useful and important, it must be seen as information that will feed into the REMP when it is applied fully. Biological information was available for inverts only and at sites that pertained to non-EWR sites. DWS:RQIS has been in contact with the PSP in August 2017 to confirm localities of EWR sites in the Lower Orange to ensure these sites are included in future monitoring programmes.
		There is need to see some reference for the habitat preferences provided for the invertebrate indicator taxa.		Habitat preferences and requirements of the various invertebrate taxa are provided in the MIRAI. This provides a semi quantitative rating of the intolerances (based on SASS weights), substrate and velocity preference. More detail is provided in Thirion (2007).