water and sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments

ECOLOGICAL WATER REQUIREMENTS REPORT

FINAL
February 2023

Department of Water and Sanitation

Chief Directorate: Water Ecosystems Management

PROJECT NUMBER**:** WP 11387

Ecological Water Requirements Report

CLASSIFICATION OF SIGNIFICANT WATER RESOURCES AND DETERMINATION OF RESOURCE QUALITY OBJECTIVES FOR WATER RESOURCES IN THE USUTU TO MHLATHUZE CATCHMENTS

FEBRUARY 2023

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REPORT SCHEDULE

Index Number	DWS Report Number	Report Title
1	WEM/WMA3/4/00/CON/CLA/0122	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Inception Report including Gap Analysis chapter**
2	WEM/WMA3/4/00/CON/CLA/0222	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Status Quo and Delineation of Integrated Units of Analysis and Resource Unit Report**
3	WEM/WMA3/4/00/CON/CLA/0322	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Resource Units Delineation and Prioritisation Report**
4	WEM/WMA3/4/00/CON/CLA/0422	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Hydrology Systems Analysis Report**
5	WEM/WMA3/4/00/CON/CLA/0522	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **River EWR estimates for Desktop Biophysical Nodes Report**
6	WEM/WMA3/4/00/CON/CLA/0622	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **River Survey Report**
7	WEM/WMA3/4/00/CON/CLA/0722	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Basic Human Needs Report**
8	WEM/WMA3/4/00/CON/CLA/0822	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Groundwater Report**
9	WEM/WMA3/4/00/CON/CLA/0922	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **River specialist meeting Report**
10	WEM/WMA3/4/00/CON/CLA/1022	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Estuary Survey Report**
11	WEM/WMA3/4/00/CON/CLA/1122	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Wetland Report**
12	WEM/WMA3/4/00/CON/CLA/1222	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Ecological Water Requirements Report**
13	WEM/WMA3/4/00/CON/CLA/1322	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Scenario Description Report**

Index Number	DWS Report Number	Report Title
14	WEM/WMA3/4/00/CON/CLA/0123, volume 1	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Ecological Consequences Report, Volume 1: Rivers**
	WEM/WMA3/4/00/CON/CLA/0123, volume 2	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Ecological Consequences Report, Volume 2: Estuaries**
15	WEM/WMA3/4/00/CON/CLA/0323	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Ecosystem Services Consequences Report**
16	WEM/WMA3/4/00/CON/CLA/0423	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Economic & User water quality Consequences Report**
17	WEM/WMA3/4/00/CON/CLA/0523	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Water Resource Classes Report**
18	WEM/WMA3/4/00/CON/CLA/0623, volume 1	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Resource Quality Objectives Report, Volume 1: Rivers**
	WEM/WMA3/4/00/CON/CLA/0623, volume 2	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Resource Quality Objectives Report, Volume 2: Estuaries**
	WEM/WMA3/4/00/CON/CLA/0623, volume 3	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Resource Quality Objectives Report, Volume 3: Wetlands and Groundwater**
19	WEM/WMA3/4/00/CON/CLA/0723	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Monitoring and Implementation Report**
20	WEM/WMA3/4/00/CON/CLA/0124	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Main Report**
21	WEM/WMA3/4/00/CON/CLA/0224	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Issues and Responses Report**
22	WEM/WMA3/4/00/CON/CLA/0324	Classification of Significant Water Resources and Determination of Resource Quality Objectives for Water Resources in the Usutu to Mhlathuze Catchments: **Close out Report**

Shaded Grey indicates this report.

APPROVAL

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Author(s):	*Louw, D., Birkhead, A., Deacon, A., Koekemoer, S., Kotze, P., Mackenzie, J., Rowntree, K., Scherman, P., Seago, C.J. and Van Niekerk, L.*
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.....20/02/2023.....

CJ Seago
Study Leader

Date

Approved for the Department of Water and Sanitation by:

20/02/2023

Ms Mohlapa Sekoele
Project Manager

21/2/2023

Ms Lebogang Matlala
Director: Water Resource Classification of
CD: Water Ecosystems Management

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Sekoele, M	DWS: Water Resource Classification
Sawunyama, T	Manager: Resource Planning and Operations (IUCMA)
Pillay, R	DWS: Regional Office, Water Quality Planning
Mazibuko, MJ	Reserve Determination: Surface Water Reserve Determination

AUTHORS

The following persons contributed to this report:

Author	Company
Louw, Delana	Rivers for Africa
Birkhead, Andrew	Streamflow Solutions
Deacon, Andrew	Private Consultant
Koekemoer, Shael	Koekemoer Aquatic Services
Kotze, Piet	Clean Stream Biological Services
Mackenzie, James	MacKenzie Ecological & Development Services
Rowntree, Kate	Private Consultant
Scherman, Patsy	Scherman Environmental
Seago, Caryn	WRP Consulting Engineers
Van Niekerk, Lara	CSIR

EXECUTIVE SUMMARY

BACKGROUND

Chapter 3 of the National Water Act, 1998 (NWA) (Act 36 of 1998), deals with the protection of water resources. Section 12 of the NWA requires the Minister to develop a system to classify water resources. In response to this, the Water Resource Classification System (WRCS) was gazetted on 17 September 2010 and published in the Government Gazette no. 33541 as Regulation 810. The WRCS is a step-wise process, whereby water resources are categorised according to specific classes that represent a management vision of a particular catchment. This vision takes into account, the current state of the water resource, the ecological, social, and economic aspects that are dependent on the resource. Once significant water resources have been classified through the WRCS, Resource Quality Objectives (RQOs) have to be determined to give effect to the class.

The Chief Directorate: Water Ecosystems Management (CD: WEM) of the Department of Water and Sanitation (DWS), initiated a study to determine the Water Resource Classes and RQOs for all significant water resources in the Usutu to Mhlathuze Catchment. The Usutu to Mhlathuze Catchments are amongst many water-stressed catchments in South Africa. These catchment areas are important for conservation, and contain a number of protected areas such as natural heritage sites, cultural and historic sites, as well as other conservation areas that need protection.

STUDY AREA

The study area is the Usutu to Mhlathuze Catchment, which has been divided into six drainage areas, as well as secondary catchment areas:

- W1 catchment (main river: Mhlathuze).
- W2 catchment (main river: Umfolozi).
- W3 catchment (main river: Mkuze).
- W4 catchment (main river: Pongola) - part of this catchment area falls within Eswatini.
- W5 catchment (main river: Usutu) - much of this catchment falls within Eswatini.
- W7 catchment (Kosi Bay and Lake Sibaya).

PURPOSE OF THIS REPORT

The purpose of this report is to document the EcoClassification and Ecological Water Requirements (EWR) results of the eight river EWR sites in the Usutu to Mhlathuze Catchment, as well as input on estuary ecological states. The results form part of Task 3: Quantify Basic Human Needs (BHN) and EWR.

RESULTS

A summary of the EcoClassification results and EWR per site is provided below.

EWR MA1: Matigulu River								
							Coordinates	S29.02010 E31.47040
							SQ[1] code	W11A-03612
							RU[2]	RU W11-2
							IUA[3]	IUA W11
							Level 2 EcoRegion	17.01
							Geomorph Zone[4]	Upper foothills
PRESENT ECOLOGICAL STATE: PES								
I IHI[5]	**R IHI[6]**	**PC[7]**	**Geom[8]**	**Rip Veg[9]**	**Fish**	**Inverts[10]**	**Instream**	**EcoStatus**
B/C (80%)	**B/C (78%)**	**B (84.5%)**	**B (87%)**	**B/C (79.4%)**	**B (86.4%)**	**B/C (80.9%)**	**B (83.3%)**	**B/C (81.3%)**
ECOLOGICAL IMPORTANCE AND SENSITIVITY								
MODERATE								
RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES								
REC = B/C for ECOSTATUS								
ECOLOGICAL WATER REQUIREMENTS (EWR)								
Natural MAR: 55.17 MCM[11]					Present day MAR: 41.85 MCM			
Low flow EWR					**Total flow EWR**			
MCM		% of nMAR[12]			MCM		% of nMAR	
13.04		23.6			18.75		34	

EWR NS1: Nseleni River								
							Coordinates	S28.63410 E31.92517
							SQ code	W12G-03229
							RU	RU W12-8
							IUA	IUA W12-b
							Level 2 EcoRegion	13.03
							Geomorph Zone	Lower foothills
PRESENT ECOLOGICAL STATE: PES								
I IHI	**R IHI**	**PC**	**Geom**	**Rip Veg**	**Fish**	**Inverts**	**Instream**	**EcoStatus**
B/C (81%)	**C (70.3%)**	**B (82.7%)**	**B (85%)**	**C (64.4%)**	**C (67.9%)**	**B/C (79.4%)**	**C (74.3%)**	**C (68.4%)**
ECOLOGICAL IMPORTANCE AND SENSITIVITY								
MODERATE								
RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES								
REC = C for ECOSTATUS								
ECOLOGICAL WATER REQUIREMENTS (EWR)								
Natural MAR: 31.23 MCM					Present day MAR: 31.56 MCM			
Low flow EWR					**Total flow EWR**			
MCM		% of nMAR			MCM		% of nMAR	
4.76		15.2			6.85		21.9	

EWR WM1: White Mfolozi River								
							Coordinates	S28.23146 E31.18666
							SQ code	W21H-02897
							RU	RU W21-5
							IUA	IUA W21
							Level 2 EcoRegion	14.05
							Geomorph Zone	Lower foothills
PRESENT ECOLOGICAL STATE: PES								
I IHI	**R IHI**	**PC**	**Geom**	**Rip Veg**	**Fish**	**Inverts**	**Instream**	**EcoStatus**
B/C (79.3%)	**B/C (77.4%)**	**B (84.5%)**	**B/C (78.8%)**	**B/C (81.3)**	**C (73%)**	**B/C (81.1%)**	**C (77.08**	**B/C (79.2%)**
ECOLOGICAL IMPORTANCE AND SENSITIVITY								
MODERATE								
RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES								
REC = B/C for ECOSTATUS								
ECOLOGICAL WATER REQUIREMENTS (EWR)								
Natural MAR: 222.51 MCM					Present Day MAR: 191.8 MCM			
Low flow EWR					**Total flow EWR**			
MCM		% of nMAR			MCM		% of nMAR	
54.74		24.6			89.31		40.1	

EWR BM1: Black Mfolozi River								
							Coordinates	S27.93890 E31.21030
							SQ code	W22A-02610
							RU	RU W22-1
							IUA	IUA W22
							Level 2 EcoRegion	3.1
							Geomorph Zone	Upper foothills
PRESENT ECOLOGICAL STATE: PES								
I IHI	**R IHI**	**PC**	**Geom**	**Rip Veg**	**Fish**	**Inverts**	**Instream**	**EcoStatus**
B/C (77.7%)	**C (74.4%)**	**B/C (81.8%)**	**A (93%)**	**C (74.9%)**	**C (75.9%)**	**B/C (81.2%)**	**B/C (78.9%)**	**C (76.9%)**
ECOLOGICAL IMPORTANCE AND SENSITIVITY								
MODERATE								
RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES								
REC = C for ECOSTATUS								
ECOLOGICAL WATER REQUIREMENTS (EWR)								
Natural MAR: 166.72 MCM					Present Day MAR: 144.13 MCM			
Low flow EWR					**Total flow EWR**			
MCM		% of nMAR			MCM		% of nMAR	
18.38		11			43.58		26.1	

EWR MK1: Mkuze River		
	Coordinates	S27.59210 E32.21800
	SQ code	W31J-02480
	RU	RU W31-5
	IUA	IUA W31-b
	Level 2 EcoRegion	3.08
	Geomorph Zone	Lowland

PRESENT ECOLOGICAL STATE: PES								
I IHI	**R IHI**	**PC**	**Geom**	**Rip Veg**	**Fish**	**Inverts**	**Instream**	**EcoStatus**
C (66.3%)	**C (72.1%)**	**C/D (58.3%)**	**B (82.26%)**	**C (73%)**	**C (75.4%)**	**C (77.7%)**	**C (76.6%)**	**C (74.8%)**

ECOLOGICAL IMPORTANCE AND SENSITIVITY
HIGH
RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES
REC = B for ECOSTATUS (Impacts non-flow related and flows will be set for a C EC)

ECOLOGICAL WATER REQUIREMENTS (EWR)			
Natural MAR: 158.75 MCM		Present Day MAR: 106.13 MCM	
Low flow EWR		**Total flow EWR**	
MCM	% of nMAR	MCM	% of nMAR
34.74	21.9	58.87	37.1

EWR UP1: Pongola River		
	Coordinates	S27.36413 E30.96962
	SQ code	W42E-02221
	RU	RU W42-2
	IUA	IUA W42-b
	Level 2 EcoRegion	3.1
	Geomorph Zone	lower/upper foothills

PRESENT ECOLOGICAL STATE: PES								
I IHI	**R IHI**	**PC**	**Geom**	**Rip Veg**	**Fish**	**Inverts**	**Instream**	**EcoStatus**
B/C (80.5%)	**B/C (77.8%)**	**A/B (88.3%)**	**A/B (89.8%)**	**C (70%)**	**C (73.9%)**	**B/C (79.5%)**	**C (77%)**	**C (73.5%)**

ECOLOGICAL IMPORTANCE AND SENSITIVITY
MODERATE
RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES
REC = C for ECOSTATUS

ECOLOGICAL WATER REQUIREMENTS (EWR)			
Natural MAR: 356.84 MCM		Present Day MAR: 299.39 MCM	
Low flow EWR		**Total flow EWR**	
MCM	% of nMAR	MCM	% of nMAR
54.84	15.4	97.31	27.3

EWR AS1: Assegaai River

Coordinates	S27.06230 E30.98880
SQ code	W51E-02049
RU	RU W51-3
IUA	IUA W52
Level 2 EcoRegion	4.06
Geomorph Zone	lower/upper foothills

PRESENT ECOLOGICAL STATE: PES

I IHI	R IHI	PC	Geom	Rip Veg	Fish	Inverts	Instream	EcoStatus
C/D (59.1%)	C/D (58.7%)	B/C (80.6%)	C (70.84%)	C (69.9)%	C (69.2%)	B/C (78.6%)	C (77.8%)	C (74.16%)

ECOLOGICAL IMPORTANCE AND SENSITIVITY

MODERATE

RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES

REC = C for ECOSTATUS

ECOLOGICAL WATER REQUIREMENTS (EWR)

Natural MAR: 328.61 MCM		Present Day MAR: 164.11 MCM	
Low flow EWR		**Total flow EWR**	
MCM	% of nMAR	MCM	% of nMAR
40.06	12.2	70.85	21.6

EWR NG1: Ngwempisi River

Coordinates	S26.679448 E30.70213
SQ code	W53E-01790
RU	RU W53-3
IUA	IUA W52
Level 2 EcoRegion	11.04/4.06
Geomorph Zone	Upper foothills/ Transitional

PRESENT ECOLOGICAL STATE: PES

I IHI	R IHI	PC	Geom	Rip Veg	Fish	Inverts	Instream	EcoStatus
C (64.3%)	C/D (61.8%)	B (85.5)	B (83.3.%)	B/C (77.4%)	C (72.8%)	B (87.3%)	B/C (80.36%)	B/C (79.8%)

ECOLOGICAL IMPORTANCE AND SENSITIVITY

MODERATE

RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES

REC = B/C for ECOSTATUS

ECOLOGICAL WATER REQUIREMENTS (EWR)

Natural MAR: 156.33 MCM		Present Day MAR: 79.15 MCM	
Low flow EWR		**Total flow EWR**	
MCM	% of nMAR	MCM	% of nMAR
30.46	19.5	50.82	32.5

1 Sub-quaternary reach. 2 Resource Unit.

3 Integrated Unit of Analysis
4 Geomorphic Zone
5 Instream component of Index of Habitat Integrity.
6 Riparian component of Index of Habitat Integrity.
7 Physico-Chemical
8 Geomorphology'
9 Riparian Vegetation
10 Macro-invertebrates
11 Million Cubic Meters
12 Natural Mean Annual Runoff

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TERMINOLOGY AND ACRONYMS

BAS	Best Attainable State
CD: WEM	Chief Directorate: Water Ecosystems Management
DFFE	Department of Fisheries, Forestry and Environment
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Ecological Category
EHI	Estuary Health Index
EIS	Ecological Importance and Sensitivity
EIS	Estuary Importance Score
EPA	Estuarine Protected Area
EWR	Ecological Water Requirements
FDT	Flow Duration Table
FRAI	Fish Response Assessment Index
FROC	Frequency of Occurrence
GAI	Geomorphology Driver Assessment Index
IHI	Index of Habitat Integrity
I IHI	Instream Index of Habitat Integrity
IUA	Integrated Unit of Analysis
IUCMA	Inkomati Usuthu Catchment Management Agency
R IHI	Riparian Index of Habitat Integrity
LB	Left bank
MCB	Macro Channel Bank
MIRAI	Macroinvertebrate Response Assessment Index
MCM	Million Cubic Meters
NBA 2011	National Biodiversity Assessment 2011
nMAR	Natural Mean Annual Runoff
PC	Physico Chemical
NWA	National Water Act
nMAR	Natural Mean Annual Runoff
FROC	Frequency of Occurrence
PAI	Physico-chemical driver Assessment Index
Geom	Geomorphology
PD	Present Day
PES	Present Ecological State
REC	Recommended Ecological Category
Inverts	Macroinvertebrates
RQO	Resource Quality Objectives
RDRMv2	Revised Desktop Reserve Model version 2
RB	Right bank
VEGRAI	Riparian Vegetation Response Assessment Index
WWTW	Waste Water Treatment Works
WTW	Water Ttreatment Works
WRCS	Water Resource Classification System
RU	Resource Unit
SQ	Sub-quaternary

Velocity Depth Classes of Fish and Macroinvertebrate habitat used in descriptions:

FCS	Fast over coarse substrate
FD	Fast deep habitat
FI	Fast intermediate habitat
FS	Fast shallow habitat
FVS	Fast Very Shallow
SD	Slow deep habitat
SIC	Stones-in-Current
SS	Slow shallow habitat
VFCS	Very fast over coarse substrate

SPELLING

There are multiple references to the spelling of various Rivers, Lakes, Dams and Estuaries, depending on the source of information. For the purposes of this report, the following Table presents the selected spelling of indicated water resources and places.

Selected Spelling for this Study	**Alternate spellings**
Usutu River	Usuthu River
Mhlathuze River	Mhlatuze, uMhlatuze River
Pongola (river, Town & Pongolapoort Dam)	Phongola, Phongolo
Lake Sibaya	Lake Sibiya, Lake Sibhayi, Lake Sibhaya
Eswatini	eSwatini
Umfolozi River	Mfolozi River
Amatigulu River	Amatikulu, Matigulu River
Goedertrouw Dam	Lake Phobane
Mfuli River	Mefule River
aMatigulu/iNyoni Estuary	
Sibiya Estuary	
Mlalazi Estuary	
uMhlathuze /Richards Bay Estuary	
iNhlabane Estuary	
uMfolozi/uMsunduze Estuary	
St Lucia Estuary	
uMgobezeleni Estuary	
Kosi Estuary	
Hluhluwe Game Reserve	
iMfolozi Game Reserve	
Ithala Game Reserve	
Ndumo Game Reserve	
Tembe Elephant Reserve	
iSimangaliso Wetland Park	
Kosi Bay and Coastal Forest Area	
uMkhuze Game Reserve	

GLOSSARY

Basic Human Needs	Water needs to be set aside for basic human needs such as drinking, food preparation, and health and hygiene purposes. This is referred to as the Basic Human Needs Reserve (BHNR).
Ecological Water Requirements (EWR)	The flow patterns (magnitude, timing and duration) and water quality needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to both the quantity and quality components.
Ecosystem services	The benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth.
EcoClassification	The term used for the Ecological Classification process - refers to the determination and categorisation of the Present Ecological State (PES; health or integrity) of various biophysical attributes of rivers relative the natural or close to the natural reference condition. The purpose of the EcoClassification process is to gain insights and understanding into the causes and sources of the deviation of the PES of biophysical attributes from the reference condition. This provides the information needed to derive desirable and attainable future ecological objectives for the river.
Integrated Unit of Analysis (IUAs)	An IUA is a homogeneous area that can be managed as an entity. It is the basic unit of assessment for the Classification of water resources, and is defined by areas that can be managed together in terms of water resource operations, quality, socio-economics and ecosystem services.
Resource Quality Objectives (RQOs)	RQOs are numeric or descriptive goals or objectives that can be monitored for compliance to the Water Resource Classification, for each part of each water resource. “The purpose of setting RQOs is to establish clear goals relating to the quality of the relevant water resources” (NWA, 1998).
Sub-quaternary (SQ)	A finer subdivision of the quaternary catchments (the catchment areas of tributaries of main stem rivers in quaternary catchments), to a sub-quaternary reach or quinary level.
Target Ecological Category (TEC)	This is the ecological category toward which a water resource will be managed once the Classification process has been completed and the Reserve has been finalised. The draft TECs are therefore related to the draft Classes and selected scenario.
Water Resource Class	The Water Resource Class (hereafter referred to as Class) defines three management classes, Class I, II, and III, based on extent of use and alteration of ecological condition from the predevelopment condition.

1 INTRODUCTION

1.1 BACKGROUND

Chapter 3 of the National Water Act, 1998 (NWA) (Act 36 of 1998), deals with the protection of water resources. Section 12 of the NWA requires the Minister to develop a system to classify water resources. In response to this, the Water Resource Classification System (WRCS) was gazetted on 17 September 2010 and published in Government Gazette 33541 as Regulation 810. The WRCS is a stepwise process whereby water resources are categorised according to specific classes that represent a management vision of a particular catchment. This vision takes into account the current state of the water resource, the ecological, social and economic aspects that are dependent on the resource. Once significant water resources have been classified following the WRCS, Resource Quality Objectives (RQOs) must be determined to give effect to the class. The implementation of the WRCS therefore assesses the costs and benefits associated with utilisation versus protection of a water resource. Section 13 of the NWA requires that Water Resource Classes and RQOs be determined for all significant water resources.

Thus, the Chief Directorate: Water Ecosystems Management (CD: WEM) of the Department of Water and Sanitation (DWS) initiated a study for determining the Water Resource Classes and RQOs for all significant water resources in the Usutu to Mhlathuze Catchment. The Usutu to Mhlathuze Catchments are amongst many water-stressed catchments in South Africa. These catchment areas are important for conservation and contain a number of protected areas, natural heritage sites, cultural and historic sites as well as other conservation areas that need protection. There are five RAMSAR[1] sites within the catchment, which includes the world heritage site and St Lucia. The others are Sibaya, Kosi Bay, Ndumo Game Reserve and Turtle Beaches.

1.2 STUDY AREA

The study area is the Usutu to Mhlathuze Catchment that has been divided into six drainage areas and secondary catchment areas as follows (refer to the locality map provided as **Figure 1.1**):

- W1 catchment (main river: Mhlathuze).
- W2 catchment (main river: Umfolozi).
- W3 catchment (main river: Mkuze).
- W4 catchment (main river: Pongola) - part of this catchment area falls within Eswatini.
- W5 catchment (main river: Usutu) - much of this catchment falls within Eswatini.
- W7 catchment (Kosi Bay estuary and Lake Sibaya).

Note that all assessments within Eswatini are excluded apart from the hydrological modelling required to assess any downstream rivers in South Africa that either run through Eswatini or originate (source) in Eswatini.

[1] A Ramsar site is a wetland site designated to be of international importance under the Ramsar Convention, also known as "The Convention on Wetlands", an intergovernmental environmental treaty established in 1971 by UNESCO in the Iranian city of Ramsar, which came into force in 1975.

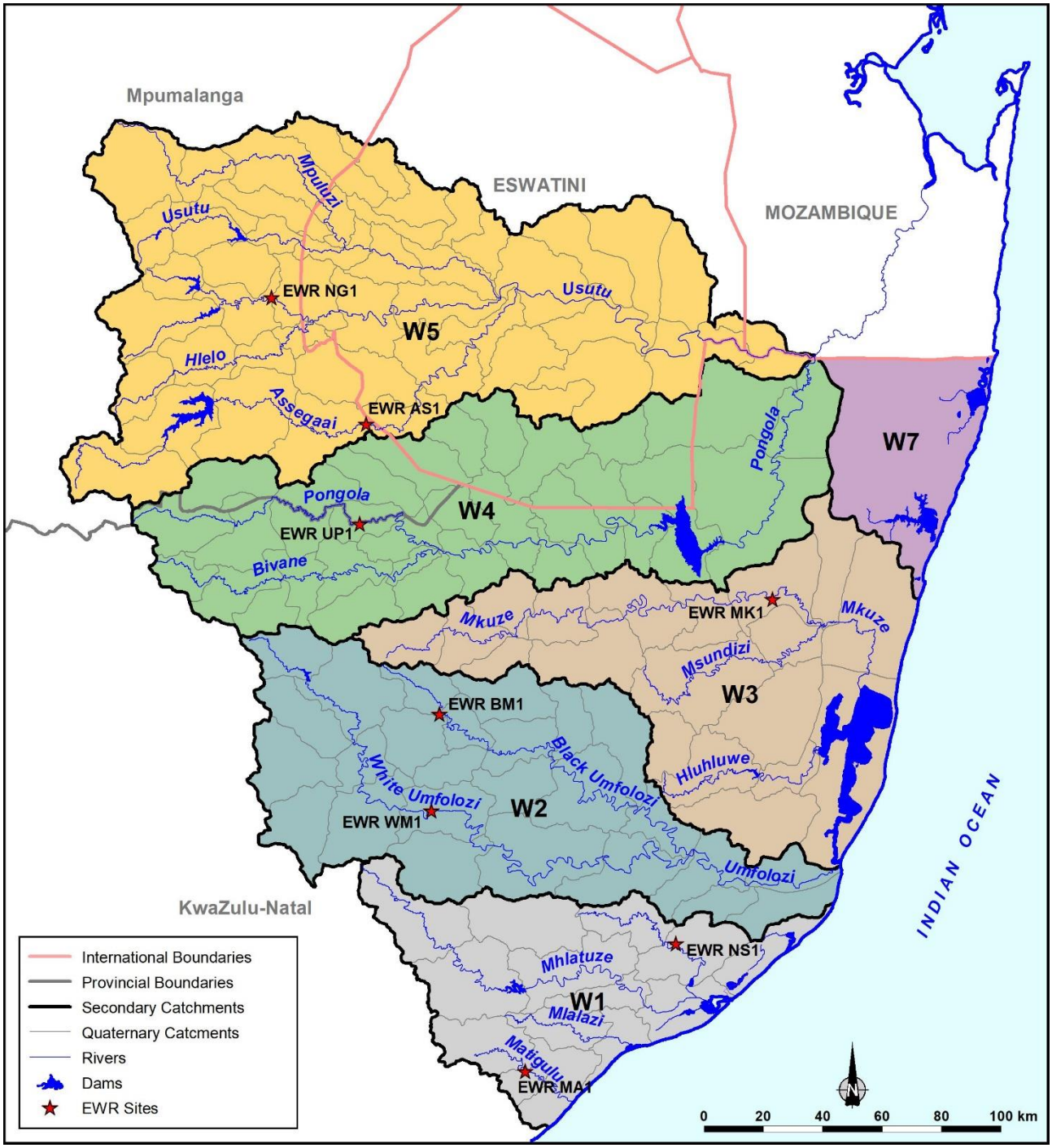
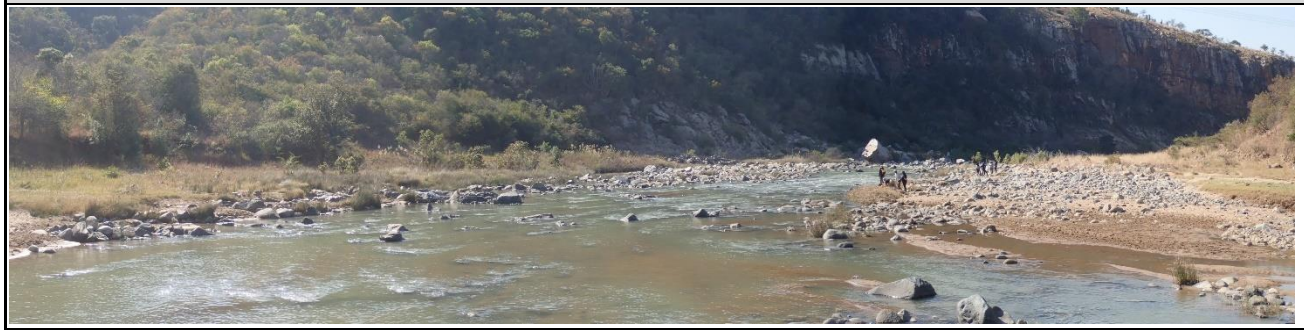


Figure 1.1 Locality Map of the Study Area showing EWR sites

1.3 EWR SITES

EWR sites were assessed as selected for the 2014 study Preliminary Reserve, with the addition of EWR NG1 on the Ngwempisi River (DWS, 2022a). The sites are summarised in **Table 1.1** and illustrated in **Figure 1.1**.

Table 1.1 EWR sites – Location information

EWR MA1: Matigulu RIver		
	Coordinates	S29.02010 E31.47040
	SQ[1] code	W11A-03612
	RU[2]	RU W11-2
	IUA[3]	IUA W11
	Level 2 EcoRegion	17.01
	Geomorphic Zone	Upper foothills
EWR NS1: Nseleni River		
	Coordinates	S28.63410 E31.92517
	SQ code	W12G-03229
	RU	RU W12-8
	IUA	IUA W12-b
	Level 2 EcoRegion	13.03
	Geomorphic Zone	Lower foothills
EWR WM1: White Mfolozi RIver		
	Coordinates	S28.23146 E31.18666
	SQ code	W21H-02897
	RU	RU W21-5
	IUA	IUA W21
	Level 2 EcoRegion	14.05
	Geomorphic Zone	Lower foothills

EWR BM1: Black Mfolozi River		
	Coordinates	S27.93890 E31.21030
	SQ code	W22A-02610
	RU	RU W22-1
	IUA	IUA W22
	Level 2 EcoRegion	3.1
	Geomorphic Zone	Upper foothills
EWR MK1: Mkuze RIver		
	Coordinates	S27.59210 E32.21800
	SQ code	W31J-02480
	RU	RU W31-5
	IUA	IUA W31-b
	Level 2 EcoRegion	3.08
	Geomorphic Zone	Lowland
EWR UP1: Pongola River		
	Coordinates	S27.36413 E30.96962
	SQ code	W42E-02221
	RU	RU W42-2
	IUA	IUA W42-b
	Level 2 EcoRegion	3.1
	Geomorphic Zone	lower/upper foothills

EWR AS1: Assegaai River		
	Coordinates	S27.06230 E30.98880
	SQ code	W51E-02049
	RU	RU W51-3
	IUA	IUA W52
	Level 2 EcoRegion	4.06
	Geomorphic Zone	lower/upper foothills
EWR NG1: Ngwempisi River		
	Coordinates	S26.679448 E30.70213
	SQ code	W53E-01790
	RU	RU W53-3
	IUA	IUA W52
	Level 2 EcoRegion	11.04/4.06
	Geomorphic Zone	Upper foothills/ Transitional

1 Sub-quaternary 2 Resource Unit
3 Integrated Unit of Analysis

1.4 PURPOSE OF THIS REPORT

The purpose of this report is to document the EcoClassification and Ecological Water Requirements (EWR) results of the eight river EWR sites in the Usutu to Mhlathuze Catchment, as well as input on estuary ecological states. The results forms part of Task 3: Quantify BHN and EWR (**Figure 1.2**).

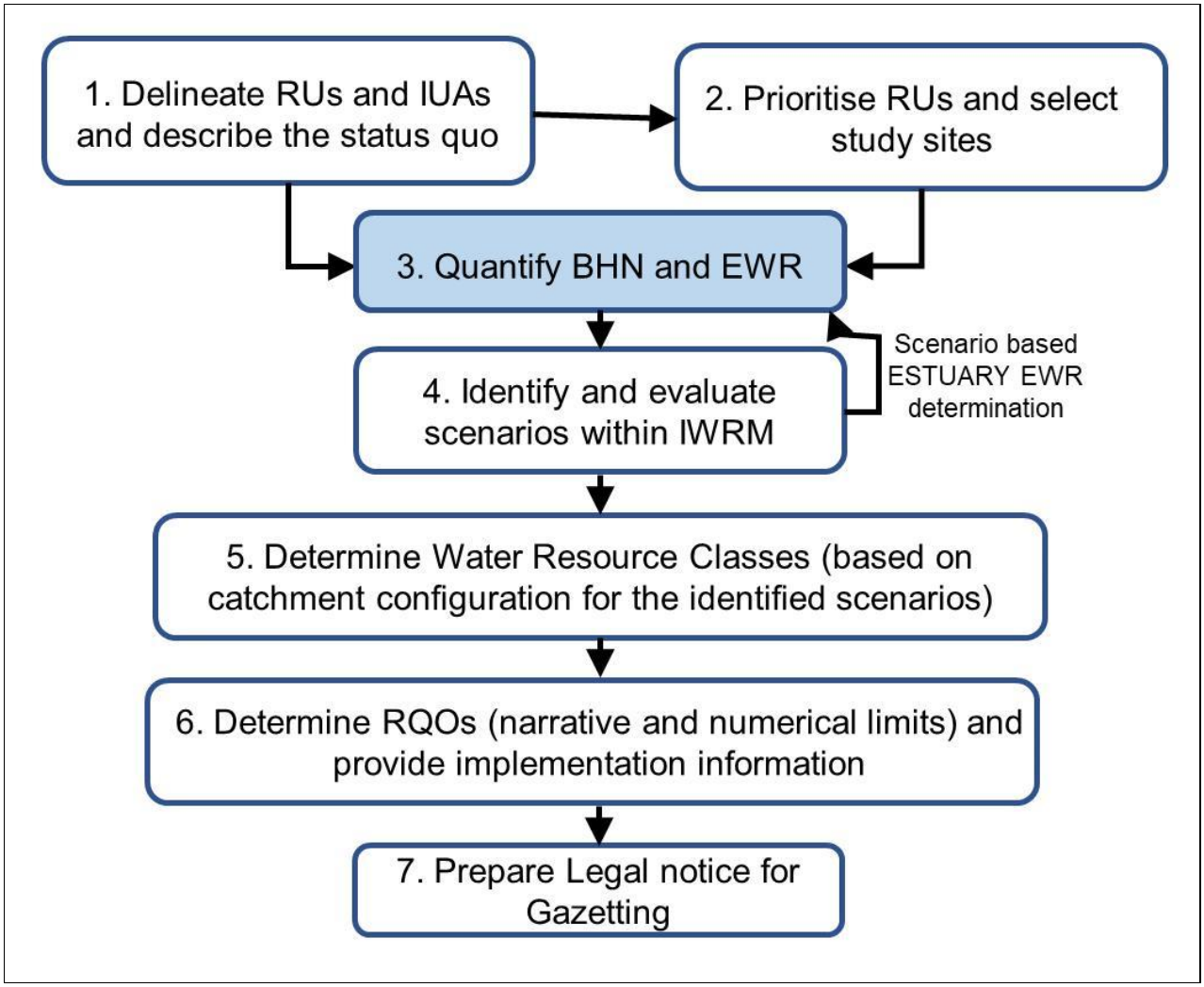


Figure 1.2 Project Plan for the Usutu-Mhlathuze Classification study

1.5 REPORT OUTLINE

The report outline is as follows:

- **Chapter 1** provides general background information on the study area and the Project Plan. This chapter also provides a general overview of the EWR sites that were assessed as part of Task 3.
- **Chapter 2 – 3** outlines the methods followed during the Ecological Reserve process. Summarised methods are provided for the EcoClassification and EWR determination.
- **Chapter 4 – 11** provides the results of EcoClassification and EWR determination per site.
- **Chapter 12** provides the provisional estuary EcoClassification results.
- **Chapter 13** consists of a summary and conclusion of the process followed.
- **Chapter 14** lists the references used in the report.

2 ECOCLASSIFICATION APPROACH

The EcoClassification process was followed according to the methods of Kleynhans and Louw (2007a). Information provided in the following sections is a summary of the EcoClassification approach. For more detailed information on the approach and suite of EcoStatus methods and models, refer to:

- Physico-chemical Driver Assessment Index (PAI): Kleynhans *et al.* (2005); DWAF (2008a).
- Geomorphology Assessment Index (GAI): Rowntree (2013).
- Fish Response Assessment Index (FRAI): Kleynhans (2007).
- Macroinvertebrate Response Assessment Index (MIRAI): Thirion (2007).
- Riparian Vegetation Response Assessment Index (VEGRAI): Kleynhans *et al*. (2007b).
- Index of Habitat Integrity (IHI): Kleynhans *et a*l. (2009).

EcoClassification refers to the determination and categorisation of the Present Ecological State (PES) (health or integrity) of various biophysical attributes of rivers compared to the natural (or close to natural) reference condition. The purpose of EcoClassification is to gain insight into the causes and sources of the deviation of the PES of biophysical attributes from the reference condition. This provides the information needed to derive desirable and attainable future ecological objectives for the river. The EcoClassification process also supports a scenario-based approach where a range of ecological endpoints has to be considered.

The state of the river is expressed in terms of biophysical components:

- Drivers (physico-chemical, geomorphology, hydrology), which provide a particular habitat template; and
- Biological responses (fish, riparian vegetation and macroinvertebrates).

Different processes are followed to assign a category (A→F; A = Natural, and F = critically modified) to each component. Ecological evaluation in terms of expected reference conditions, followed by integration of these components, represents the Ecological Status or EcoStatus of a river. The EcoStatus can therefore be defined as the totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna (modified from: Iversen *et al*., 2000). This ability relates directly to the capacity of the system to provide a variety of goods and services.

3 EWR DETERMINATION APPROACH

The EWRs were determined during the 2014 Preliminary Reserve study (DWS, 2014). The same sites were used, with one additional site included during this 2022 study. The EWRs determined during 2014 were updated using the current systems hydrology which is used for yield modelling. The approach followed consisted of:

- Providing a Version 2 of the Revised Desktop Reserve Model (RDRMv2 - Hughes *et al*. 2014) EWR estimate.
- Adjusting the low flows based on specialist input.
- Adjusting the high flows based on specialist input.
- Remodelling the EWR using the RDRM v2 to provide the EWR recommendations.

3.1 DESKTOP APPROACH

The Revised Desktop Reserve Model (RDRM, v2) was used to estimate the EWRs for the sites (refer to Hughes *et al*., 2012; 2014 and 2018). The timeseries of natural and present day monthly flows was supplied by WRP Consulting Engineers (Pty) Ltd (DWS, 2022b).

A field trip to the EWR sites took place during 2013 and 2014 (DWS, 2014) and July 2022. Topographical and hydraulic information which were collected during these site visits were used as input into the RDRM. The input was in the format of a cross-sectional profile and the modelling of the rating (or stage-discharge) relationship.

Velocity-depth class weighting factors and stress index values at zero fast flow were derived from predicted fish species for the river reach, as described by Hughes *et al*. (2018). Default (i.e. 'desktop') shifts were applied to compute stress-duration and hence discharge-duration relationships (for the various ecological Categories) relative to natural. The default high-flow component was used, but checked using riparian indicators.

3.2 LOW FLOW EWR

The low flow EWR used the following approach to review the RDRM v2 EWR estimates:

- The Flow Duration Table (FDT) desktop low flow EWR for the PES Ecological was extracted from the model output.
- The low flows for the 60th and 90th percentiles for the wettest and driest month was converted to m^3/s and was assessed by the instream specialists to determine whether the flows were sufficient.
- If the discharges were not adequate, then a motivated adjusted discharge was recommended.
- Adjustments were made in the Desktop model to achieve the revised low flow regime.

3.3 HIGH FLOW EWR

The high flow EWR used the following approach to review the Desktop EWR result. The desktop model provides a peak, frequency, number of floods and durations. The high flow specialists evaluated the floods and recommend changes in the peak, and number of floods.

4 EWR MA1: MATIGULU RIVER

4.1 PRESENT ECOLOGICAL STATE

The Present Ecological State (PES) for each component as well as for the EcoStatus are summarised in **Table 4.1** below

Table 4.1 Present Ecological State: Results and comments

Component	PES	Comment
Instream IHI	**B/C (80%)**	The dominant impacts are on bed modification based on increase sedimentation (catchment use) and benthic growth and are non-flow related. **Confidence 3.3**
Riparian IHI	**B/C (78%)**	The key impacts are non-flow related and are based on bank structure changes in the non-marginal zone as well as longitudinal and lateral connectivity issues based on presence of alien vegetation. **Confidence 3**
Water quality	**B (84.5%)**	The EWR site is located in the upper reaches of the sub-quaternary (SQ) reach. Note that the lower reach was identified as a water quality priority area due to effluents from the Amaticulu Sugar Mill, cultivation and sand-mining. High settlement density is present on the ridges at the site. Despite stable banks, there is evidence of sand deposits in fast flow environments. The water quality state is driven by salts and turbidity, with a small increase in nutrients. The integrated category is the same as the 2014 assessment (82.38% vs 84.5% in 2022). **Confidence: 2.5** due to poor dataset available for analysis.
Geomorphology	**B (87%)**	Increased sediment from settlements and cultivated fields. Some fine sediment patches in runs and pools. Good cover on adjacent hillslopes. No significant change from 2014. **Confidence: 3.25**
Riparian vegetation	**B/C (79.4%)**	The marginal zone was dominated by non-woody vegetation, mostly reeds, sedges and grasses, with high vegetative cover. The sub-zone was mostly cobble and boulder with some alluvial deposits. Dominant habitats included grass in the water (*Ishaemum faciculatum*), sedge and grass banks and reed clumps in the water. Impacts were low, with cattle at the site (no overgrazing prevalent), low prevalence of aliens and no large dams upstream. Water abstraction and farm dams would have reduced flow, and resulted in some regulation. The lower zone was dominated by non-woody vegetation but with scattered prevalence of *Syzygium gerrardii, S. cordatum* and *Ficus sycomorus*. Grasses dominated but common habitats included reed beds (patches) and cobble sedge / grass bars. *S. guieneense, B. salicina* and *C. erythrophyllum* were absent. The upper zone consisted of mixed woody and non-woody vegetation with a distinct absence of tall trees. This may be due to recent large floods or wood harvesting. *C. erythrophyllum*, large *Ficus* and *T. emetica* were absent. The macro channel bank (MCB) was mostly steep, dominated by woody vegetation and the prevalence of terrestrial species was high. This suggests reduced flooding disturbance. Woody vegetation was dominated by *Vachellia* species, while *S. africana* was absent. **Confidence: 3**
Fish	**B (86.4%)**	Of the 20 fish species expected under reference conditions, five species were collected during the course of the 2014 survey. Three indigenous fish species were sampled during 2022 with *M. falciformis* being the most abundant, followed by *Labeobarbus natalensis*. After various refinements to the initial FRAI, a score of 86.4% was calculated (2022). The primary causes for the slightly reduced biotic conditions are related to slightly reduced flows (all months), slight water quality deterioration (salts and nutrients) and slight sedimentation (catchment erosion). **Confidence: 3**
Macro-invertebrates	**B/C (80.9%)**	The presence of six taxa with a preference for moderately fast flowing water and an abundance of stones-in-current habitat, indicate favourable conditions at this site. Three taxa with a moderate requirement for unmodified physico-chemical conditions are also present and which added to the favourable MIRAI score. **Confidence: 3**
Instream	**B (83.3%)**	The Instream PES was derived using the EcoStatus model.
EcoStatus	**B/C (81.3%)**	The EcoStatus PES was derived using the EcoStatus model.

Table 4.2 Present Ecological State: Key flow and non-flow related impacts

Component	Causes	Sources	Flow or non-flow related
Water quality	Elevated turbidities and salts; small increase in nutrient levels.	Sedimentation from overgrazing and erosion. Elevated salts from cultivation activities and presence of rural settlements.	Non-flow
Geomorphology	Increased sand deposits.	Catchment erosion.	Non-flow
Riparian vegetation	Altered species composition.	Alien plant species (perennial and invasive, including *Sesbanea, Chromolaena, Ageratum*).	Non-flow
Fish	Decreased habitat availability due to lower flows, deteriorated water quality, sedimentation.	Water abstraction, settlements and catchment erosion.	Flow and non-flow
Macroinvertebrates	Sensitive taxa impacted by deteriorating water quality parameters (increased nutrients and salinity), as well as increased sedimentation.	Catchment erosion and donga formation. Trampling and grazing result in erosion.	Non-flow

In summary, the B/C EcoStatus represents the response of the biota to sedimentation as a result of overgrazing, erosion and the presence of alien vegetation as well as general catchment erosion.

4.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The Ecological Importance and Sensitivity (EIS) evaluation resulted in **MODERATE** importance. The highest scoring metrics were:

- Rare and endangered fish species.
- Diversity of instream habitat types.
- Rare and endangered riparian and wetland biota and biomes.
- Riparian / wetland species/taxon richness.
- Riparian habitat diversity of types and features.

4.3 RECOMMENDED ECOLOGICAL CATEGORY

Due to the **MODERATE** importance, the Recommended Ecological Category (REC) is set to maintain the PES of a **B/C Ecological Category (EC)**.

4.4 LOW FLOW ECOLOGICAL WATER REQUIREMENTS

The low flow requirements as an initial estimate from the RDRM model was provided to specialists for a review and are summarised in **Table 4.3**.

Table 4.3 Low flow EWR review and recommendations: B/C PES

Month	Percentile	Discharge (m^3/s)	Review[1]	Recommended discharge (m^3/s)	Final discharge (m^3/s)
Aug	90th	0.170	**FISH:** RDRM discharge (0.17 m^3/s) will result in stress of 6.5. At this discharge some fast habitats (Fast-Deep (FD): 1%, Fast-Intermediate (FI):1%, and Fast-Shallow (FS):3%), max. depth (0.39 m) will be provided. These habitats should be adequate to meet requirements of indicator spp. (*Labeobarbus natalensis*) and hence also meet the requirements of other moderately intolerant species in the reach. The lowest recommended discharge for dry season (droughts) is 0.15 m^3/s (stress 7.1). Very limited fast habitats (4%) will be available and a further decrease will result in potential loss of FD. This could also result in water quality deterioration (especially oxygen) that may jeopardize the survival of intolerant fish species during these high stress periods. **INVERTS:** At RDRM discharge, 3% FS/FI, as well as 1% Fast-Deep habitat will be available. The important fast flow habitats will be adequate for the following indicators taxa: Cobble dwellers - Palaemonidae, Perlidae and Hydropsychidae; and sensitive species (Elmidae) will be able to tolerate moderate flows (0.1 to 0.3 m/s). Vegetation dwellers such as Coenagrionidae will survive in pools during the Dry Drought at a stress level of 7.1.	0.150	0.140
Aug	60th	0.360	**FISH**: RDRM discharge (0.36 m^3/s) result in stress of 3.9. At this discharge moderate availability of fast habitats and adequate depth will be maintained (FD: 4%, FI: 5%, FS: 4%, max. depth: 0.48 m). These habitats will be more than adequate to meet requirements of indicator spp. (*Labeobarbus natalensis*). The lowest recommended discharge for dry season (maintenance) is 0.28 m^3/s (stress 4.6). Although less fast habitats will be available these should provide adequate habitat and WQ for indicator species (and others) during dry seasons. **INVERTS:** At RDRM discharge, 11% of the available aquatic biotopes will consist of fast flows. The higher water levels will support most of the local aquatic biotopes (at a stress level of 3.9) and improve movement between habitats (migratory Palaemonidae). It will also extend habitat for other indicator species such as Coenagrionidae in inundated marginal vegetation habitats.	0.280	0.270
March	90th	0.010	**FISH:** RDRM discharge (0.01 m^3/s) will result in extremely high stress of 9.1. At this discharge no fast habitats will be available and max depth (0.17 m) will also be inadequate. These habitats will not be adequate to sustain the fish assemblage in the PES. It is recommended that the discharge should not be allowed to go lower than 0.17 in wet season (droughts). Although the stress will be high (8.1) some fast habitats (FD: 1%, FI: 1% and FS:	0.170	0.140

Month	Percentile	Discharge (m^3/s)	Review[1]	Recommended discharge (m^3/s)	Final discharge (m^3/s)
			4%) will be available to meet the flow requirements of all life stages (feeding, breeding, migration) of the indicator spp. (*Labeobarbus natalensis*). **INVERTS:** At RDRM discharge, 3% of the available aquatic biotopes will consist of FS/FI habitat. These flows will result in restricted fast flowing habitat at a stress level of 8.1. Flows and habitat for Palaemonidae, Perlidae, Hydropsychidae and Heptageniidae will also be restricted, as limited flows between 0.1 to 0.3 m/s will be available. Vegetation dwellers such as Coenagrionidae will survive in pools during the Wet Drought season.		
March	60th	0.217	**FISH:** RDRM discharge (0.217 m^3/s) results in moderate stress of 7.8. At this discharge some fast habitats (FD: 2%, FI: 1%, and FS: 3%) with max. depth of 0.42 m will be provided. Although these habitats may be able to meet the flow requirements of all life stages (feeding, breeding, migration) of the indicator spp. (*Labeobarbus natalensis*) it is recommended that a higher discharge (0.35 m^3/s) should be maintained (to attain fish PES of B). At this discharge stress will be 7.3 and adequate fast habitats (FD: 4%, FI: 5%, FS: 2%) and depth and water quality will be maintained to meet all life-stage requirements of indicator spp (*Labeobarbus natalensis*). **INVERTS:** At RDRM discharge, 7% FS/FI, as well as 4% FD habitat will be available. The higher water levels will support most of the local aquatic biotopes (at a stress level of 7.3) and improve movement between habitats (migratory Palaemonidae). It will also extend habitat for other indicator species such as Coenagrionidae in inundated marginal vegetation habitats.	0.350	0.380

1 Velocity Depth Classes of Fish and Macroinvertebrate habitat used in descriptions:

FD: Fast deep habitat FI: Fast intermediate habitat
FS: Fast shallow habitat FVS: Fast Very Shallow
SD: Slow deep habitat SS: Slow shallow habitat
FCS: Fast over coarse substrate SIC: Stones-in-Current
VFCS: Very fast over coarse substrate

4.5 HIGH FLOW EWR

The high flow EWR as output from the RDRM model was provided to specialists for review (**Table 4.4**).

Table 4.4 Desktop EWR high flow recommendations

Class	Frequency	Peak (m3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	1.968	33	4	0.096
2	Annual	6.164	37	3	0.339
3	Annual	16.109	37	1	0.886
4	1:2year	56.257	41	1	3.436
5	1:5 year	182.173	49	1	13.341

Adjustments to the high flow EWR are indicated and motivated in **Table 4.5**.

Table 4.5 Desktop EWR high flow recommendations

Class	Frequency	Peak (m^3/s)	Vegetation Motivation	Geomorphology Motivation
1	Annual	2	Required to inundate marginal zone vegetation. Prevents establishment of terrestrial or alien species in the marginal zone. Provides recruitment opportunities in the marginal and lower zones. Stimulates growth and reproduction. Prevents encroachment of marginal zone vegetation towards the channel. At the site activates marginal zone sedges (*Cyperus longus*, *Juncus oxycarpus*). The desktop estimation of 5.1 m^3/s is acceptable for riparian vegetation.	Potential to deposit fine sediment within marginal zone; limited entrainment and transport of very fine gravels.
2	Annual	6	Required to flood marginal zone and lower portion of lower zone. Prevents establishment of terrestrial or alien species in marginal and lower zones. Stimulates growth and reproduction. Prevents encroachment of marginal zone vegetation towards the channel. Inundates marginal zone graminoids (*Cyperus longus, Juncus oxycarpus, Pennisetum natalensis, Phragmites mauritianus*). The desktop estimation of 11.5 m^3/s is acceptable for riparian vegetation.	Inundates channel edge of flood bench; will deposit sediment (sand) in this area and help to maintain this feature; entrainment and transport of coarse sand across main channel, limited entrainment and transport of coarse sand and fine gravels.
3	Annual	16	Required to inundate lower zone vegetation and activate upper zone vegetation. This flood class has similar functions to class 1 and 2 floods and also maintains heterogeneity in the marginal zone and prevents dominance by species / guilds. Floods marginal zone and activates lower	Inundates back of flood bench; will deposit sediment (sand) towards back of the bench; entrainment and transport of very coarse sand across main channel, and limited entrainment and transport of fine gravels.

Class	Frequency	Peak (m^3/s)	Vegetation Motivation	Geomorphology Motivation
			zone trees (*Syzygium gerardii, S. cordatum)*. The desktop estimation of 24.2 m^3/s is acceptable for riparian vegetation.	
4	1:2 year	56	Required to inundate lower portion of the upper zone. Similar functions to above. Scour marginal and lower zones, maintain vegetation patchiness and heterogeneity. Activates and inundates flood feature riparian trees (*Nuxia oppositifolia, Ficus sycomorus*). The desktop estimation of 62.3 m^3/s is acceptable for riparian vegetation.	Overtops the sandy ridge on left bank (LB); inundates lower section of MCB; entrainment and transport of fine gravels across main channel, and limited entrainment and transport of medium gravel.
5	1:5 year	180	Required to inundate upper zone macro channel and some portion of the MCB. Similar functions to above. Scour marginal, lower and upper zones, maintain vegetation patchiness and heterogeneity. Prevents terrestrialisation of the riparian zone. Floods to *Vachellia robusta* (Terrestrial tree line). The desktop estimation of 184.1 m^3/s is acceptable for riparian vegetation.	Reset flood for bed sediments; entrainment and transport of fine gravel across main channel, limited entrainment and transport of small cobbles.

4.6 EWR MA1 RECOMMENDATIONS FOR A B/C ECOLOGICAL CATEGORY

The flow requirements are summarised in **Table 4.6** to **4.8**. **The low flow EWR** is 13.04 Milion Cubic Meters (MCM) and equates to 23.6% of the natural mean annual runoff (nMAR). The **Total flow EWR** is 18.745 MCM which equates to 34% of the nMAR. The text in red on the flow duration tables refers to the wettest (March) and driest (August) months.

Table 4.6 Final high flow requirements

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	1.968	33	4	0.096
2	Annual	6.164	37	3	0.339
3	Annual	16.109	37	1	0.886
4	1:2year	56.257	41	1	3.436
5	1:5 year	182.173	49	1	13.341

Table 4.7 Low flow assurance rules (m^3/s)

m^3/s	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.682	0.680	0.678	0.603	0.485	0.386	0.299	0.254	0.216	0.136
Nov	0.706	0.706	0.706	0.614	0.492	0.376	0.299	0.236	0.201	0.134
Dec	0.682	0.682	0.682	0.559	0.480	0.355	0.287	0.225	0.199	0.133
Jan	0.583	0.583	0.583	0.530	0.416	0.337	0.278	0.208	0.151	0.064
Feb	0.605	0.538	0.536	0.498	0.417	0.347	0.265	0.190	0.151	0.056
Mar[1]	0.735	0.614	0.552	0.499	0.431	0.348	0.267	0.200	0.149	0.063
Apr	0.646	0.578	0.576	0.508	0.437	0.342	0.288	0.212	0.152	0.093
May	0.643	0.595	0.589	0.517	0.433	0.352	0.290	0.225	0.162	0.094
Jun	0.560	0.559	0.557	0.515	0.444	0.358	0.294	0.233	0.174	0.100
Jul	0.583	0.583	0.583	0.529	0.442	0.358	0.295	0.239	0.180	0.106
Aug[1]	0.456	0.432	0.413	0.389	0.357	0.280	0.192	0.172	0.142	0.084
Sep	0.608	0.606	0.605	0.543	0.452	0.372	0.292	0.236	0.196	0.122

[1] The low flows for the 60th and 90th percentiles for the wettest (March) and driest (August) month.

Table 4.8 Total assurance rules (MCM)

MCM	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.581	2.161	2.155	1.711	1.396	1.068	0.802	0.679	0.578	0.364
Nov	2.716	2.188	2.169	1.687	1.372	1.07	0.776	0.612	0.522	0.348
Dec	2.714	2.167	2.008	1.594	1.382	0.952	0.768	0.602	0.533	0.355
Jan	1.900	1.900	1.900	1.516	1.211	0.902	0.745	0.556	0.404	0.172
Feb	2.241	1.652	1.589	1.311	1.114	0.846	0.646	0.463	0.369	0.136
Mar	2.854	1.984	1.762	1.433	1.25	1.029	0.716	0.536	0.399	0.168
Apr	2.424	1.836	1.831	1.451	1.228	0.983	0.747	0.549	0.395	0.24
May	2.542	1.76	1.578	1.39	1.16	0.942	0.776	0.602	0.434	0.253
Jun	2.00	1.787	1.611	1.431	1.248	0.927	0.761	0.603	0.452	0.259
Jul	1.901	1.901	1.652	1.452	1.23	0.96	0.791	0.641	0.481	0.285
Aug	1.56	1.496	1.201	1.139	1.053	0.751	0.513	0.461	0.381	0.226
Sep	1.915	1.899	1.663	1.504	1.267	0.964	0.758	0.613	0.509	0.317

5 EWR NS1: NSELENI RIVER

5.1 PRESENT ECOLOGICAL STATE

The PES for each component as well as for the EcoStatus are summarised in **Table 5.1** below.

Table 5.1 Present Ecological State results and comments

Component	PES	Comment
Instream IHI	**B/C (81%)**	The major impacts are bed and bank modification. These impacts will be non-flow related and due to alien vegetation, and the direct impact of riparian land owners. **Confidence 3.1**
Riparian IHI	**C (70.3%)**	Impacts on the riparian zone linked to largely invasive alien vegetation are the dominant cause of the status of the Riparian IHI. **Confidence 3**
Water quality	**B (82.7%)**	The EWR site is located in an area of extensive subsistence farming. Widespread erosion is evident in the upper to middle catchments due to rural settlements and related activities. Water quality state driven by salts and turbidity, with a small increase in nutrients. Integrated category the same as the 2014 assessment (83.81% vs 82.7% in 2022). **Confidence: 2.5** due to poor dataset for analysis.
Geomorphology	**B (85%)**	Widespread erosion in the middle to upper catchment due to rural settlement; bank stability reported as good (2014 report). Limited deposition of fines observed on bed of upstream site visited in 2022. **Confidence: 2.75**
Riparian vegetation	**C (64.4%)**	The marginal zone was mostly well shaded with steep banks where pools exist or else cobble areas with undercut roots. Instream root habitat and overhanging vegetation were dominant. The sub-zone was dominated by woody vegetation but where sunny more open areas exist, grasses and sedges occurred. A small amount of clearing existed for the crossing, otherwise impacts were low. Dominant species *included F. sycomorus, P. reclinata, C. sexangularis, I. fasiculatum* and *Stenotaphrum. Syzygium* and *G. virgatum* were absent. The lower zone consisted mostly of mud banks that are well shaded and exposed roots were common. Some areas of cobble bed that are more open existed and were covered by grasses and sedges. Woody vegetation, frequently tall, with a closed canopy dominated and vegetation characteristics were similar to the marginal zone. *Nuxia oppositifolia* was also a lower zone dominant, in addition to the species found on the marginal zone. *Syzygium* was absent. The upper zone consisted of steep alluvial banks with dense woody cover. The tree and shrub layer was closed canopy and shaded out the understorey. Where areas have been cleared for access alien species have heavily invaded (mostly *Chromolaena odorata* and *Lipia*). *Syzygium* and *Combretum* were absent. The banks were steep, dominated by woody vegetation and merge with terrestrial forest (kloof vegetation). Overall, an effective riparian corridor existed (dense woody belt dominated by indigenous vegetation), but alien species invasion was high in cleared areas. The banks had been extensively cleared along security fences of property and for limited access to the river. *Ilex mitis* was not observed at the site. **Confidence: 3.2**
Fish	**C (67.9%)**	Based on available information it is estimated that 26 fish species can be expected in the river reach of concern. Only two (*P. philander* and *G. callidus*) were collected at the EWR site during the July 2014 survey (no additional sampling during 2022). The FRAI model from the 2014 study was updated for the purpose of the 2022 study with a score of 67.9% (Category C) calculated. The primary drivers for change in the fish was slight sedimentation, altered flows (water transfer) and altered marginal vegetation as cover (aliens). **Confidence: 2**
Macro-invertebrates	**B/C (79.4%)**	The presence of three taxa with a preference for moderately fast flowing water and an abundance of loose cobble habitat, indicate favourable conditions at this site. Two taxa with a moderate requirement for unmodified physico-chemical conditions are also present and added to the moderate MIRAI score. **Confidence: 2**
Instream	**C (74.3%)**	The Instream PES was derived using the EcoStatus model.
EcoStatus	**C (68.4%)**	The EcoStatus EC was derived using the EcoStatus model.

Table 5.2 Present Ecological State: Key flow and non-flow related impacts

Component	Causes	Sources	Flow or non-flow related
Water quality	Elevated turbidities and salts; small increase in nutrient levels.	Sedimentation from extensive settlements and related activities. Elevated salts from cultivation activities (and marine influence).	Non-flow
Geomorphology	Limited increased fine sediment deposits.	Catchment erosion.	Non-flow
Riparian vegetation	Altered species composition.	Alien plant species (perennial and invasive, including *Sesbanea, Chromolaena, Ageratum*).	Non-flow
	Reduced vegetation cover along flood features.	Vegetation clearing for fences and security.	Non-flow
Fish	Altered habitats and flows, sedimentation and altered marginal vegetation as cover.	Agricultural runoff from Mhlathuze canal irrigation - agriculture (esp. sugar cane), catchment erosion, alien vegetation encroachment.	Flow and non-flow
Macroinvertebrates	Sensitive taxa impacted by sedimentation and siltation.	Vegetation clearing for agriculture, rural settlements and dirt roads results in widespread erosion.	Non-flow.

In summary, the C EcoStatus represents the response of the biota to the lack of habitat diversity due to sedimentation from overgrazing, erosion and removal of riparian vegetation as well as the presence of alien vegetation in the riparian zone.

5.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS evaluation resulted in a **MODERATE** importance. The highest scoring metrics were:

- Rare and endangered fish species.

5.3 RECOMMENDED ECOLOGICAL CATEGORY (REC)

Due to the moderate importance, the REC is set to maintain the PES of a **C EC**.

5.4 LOW FLOW ECOLOGICAL WATER REQUIREMENTS

The low flow requirements as an initial estimate from the RDRM model was provided to specialists for a review and are summarised in **Table 5.3**.

Table 5.3 Low flow EWR review and recommendations: C PES

Month	Percentile	Discharge not constrained to PD (m^3/s)	Review	Recommended discharge (m^3/s)	Final discharge (m^3/s)
Aug	90th	0.160	**FISH:** RDRM discharge: Stress of 6. More than adequate fast habitats (FD: 1%, FI: 4% and FS: 3%) and max. depth (0.31 m) available for most flow intolerant indicator species (*Labeobarbus natalensis*, *Labeo molybdinus*). Minimum discharge to maintain during dry season drought is 0.04 m^3/s. At this flow no FD and FI will be available but some FS and FVS will be maintained. This should be adequate to maintain WQ and pool depth to sustain viable populations of most intolerant species. **INVERTS:** At this discharge, there will be 7% FS/FI habitat available, as well as 1% FD at this site, mostly due to the narrow channel of the stream. The only rheophilic indicator invertebrate expected to require fast flows at the site, is Hydropsychidae (>0.6 m/s) and sensitive Elmidae in moderate flows (0.3 – 0.6 m/s). The low water levels will support 71% of the SS aquatic biotopes which will inundate some of the marginal vegetation habitats. The indicator for vegetation in slow flows is the Coenagrionidae, vegetation dwellers that survive in this inundated habitat at a stress level of 6.0 during Dry Drought conditions. Reduced flows recommended for fish are adequate to maintain invertebrate PES.	0.040	0.040
Aug	60th	0.310	**FISH:** RDRM discharge: Stress of 4. More than adequate fast habitats (FD: 6%, FI: 4% and FS: 3%) and max. depth (0.4 m) available for most flow intolerant indicator species (*Labeobarbus natalensis*, *Labeo molybdinus*). Minimum discharge to maintain during dry season is 0.1 m^3/s. At this flow no FD will be available but some FI, FS and FVS will be maintained. This should be adequate to maintain water quality and pool depth to sustain viable populations of most intolerant species. **INVERTS:** At this discharge, there will be 7% FS/FI habitat available, as well as 6% FD at this site, mostly due to the narrow channel of the stream. The only rheophilic indicator invertebrate expected to require fast flows at the site, is Hydropsychidae (>0.6 m/s) and sensitive Elmidae in moderate flows (0.3 – 0.6 m/s). In the favourable deeper habitat with fast flows, these assemblages will expand their distribution into these available habitats. These water levels will support 79% of the SS aquatic biotopes which will inundate the marginal vegetation habitats. The indicator for vegetation in slow flows is the Coenagrionidae, vegetation dwellers that thrive in this inundated habitat at a stress level of 4.0 during Dry Maintenance conditions. Reduced flows recommended for fish are adequate to maintain invertebrate PES.	0.100	0.100
Apr	90th	0.180	**FISH:** RDRM discharge: Stress of 6.6. Some fast habitats (FD: 1%, FI: 4% and FS: 4%) and max. depth (0.32 m) available for most flow intolerant indicator species (*Labeobarbus natalensis*, *Labeo molybdinus*). Minimum discharge to maintain during dry season drought is 0.1 m^3/s. At this discharge no FD will be available but some FI, FS and FVS will be available to provide adequate habitat, water quality and depth (migration) for all life stages of most intolerant species.	0.100	0.100

Month	Percentile	Discharge not constrained to PD (m^3/s)	Review	Recommended discharge (m^3/s)	Final discharge (m^3/s)
			INVERTS: At this discharge, there will be 8% FS/FI habitat available, as well as 1% FD at this site, mostly due to the narrow channel of the stream. The only rheophilic indicator invertebrate expected to require fast flows at the site, is Hydropsychidae (>0.6 m/s) and sensitive Elmidae in moderate flows (0.3 – 0.6 m/s). The low water levels will support 76% of the SS aquatic biotopes which will inundate ample marginal vegetation habitats. The indicator for vegetation in slow flows is the Coenagrionidae, vegetation dwellers that thrive in this inundated habitat at a 6.6 stress level during Wet Drought conditions. Reduced flows recommended for fish are adequate to maintain invertebrate PES.		
Apr	60th	0.330	**FISH:** RDRM discharge: Stress of 5. Some fast habitats (FD: 7%, FI: 5% and FS: 3%) and max. depth (0.41 m) available for most flow intolerant indicator species (*Labeobarbus natalensis*, *Labeo molybdinus*). Minimum discharge to maintain during dry season drought is 0.17 m^3/s. At this discharge some FD (1%), FI (4%) and FV (3%) will be available to provide adequate habitat, water quality and depth (migration) for all life stages of most intolerant species. **INVERTS:** At this discharge, there will be 8% FS/FI habitat available, as well as 7% FD at this site, mostly due to the narrow channel of the stream. The only rheophilic indicator invertebrate expected to require fast flows at the site, is Hydropsychidae (>0.6 m/s) and sensitive Elmidae in moderate flows (0.3 – 0.6 m/s). The low water levels will support 79% of the SS aquatic biotopes which will inundate ample of the marginal vegetation habitats. The indicator for vegetation in slow flows is the Coenagrionidae, vegetation dwellers that thrive in this inundated habitat at a 5.0 stress level during Wet Maintenance conditions. Reduced flows recommended for fish are adequate to maintain invertebrate PES.	0.170	0.160

5.5 HIGH FLOW EWR

The high flow EWR as output from the RDRM model was provided to specialists for review (**Table 5.4**).

Table 5.4 Desktop EWR high flow recommendations

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	2.842	33	4	0.139
2	Annual	6.580	37	3	0.362
3	Annual	11.511	37	1	0.633
4	1:2 year	21.251	41	1	1.298
5	1:5 year	45.137	49	1	3.306

Adjustments to the high flow EWR are indicated and motivated in **Table 5.5**.

Table 5.5 Desktop EWR high flow recommendations

Class	Frequency	Peak (m^3/s)	Vegetation Motivation	Geomorphology Motivation
1	Annual	2 - 4	Required to activate and inundate a proportion of marginal zone graminoids (*Stenotaphrum secundatum, Cyperus sexangularis*). The desktop estimation of 3.8 m^3/s is acceptable for riparian vegetation.	Mobilisation of fine sand and, to a limited extent, small gravel.
2	Annual	5	Required to inundate marginal zone riparian trees (*Ficus sycomorus*) and activate lower zone graminoids (*Cyperus sexangularis, Cyperus dives*). The desktop estimation of 8.8 m^3/s is acceptable for riparian vegetation since this achieves the same function.	Overtops flood bench allowing deposition of silt and sand; mobilises sand on the channel bed, limited mobilisation of small gravel.
3	Annual	8 - 10	Required to inundate lower zone riparian trees (*Phoenix reclinata, Ficus sycomorus*) and graminoids (*Cyperus sexangularis, Cyperus dives*). The desktop estimation of 15.1 m^3/s is acceptable for riparian vegetation since this achieves the same function.	More extensive overtopping of flood bench allowing deposition of silt and sand; mobilises sand on the channel bed, limited mobilisation of small gravel.
4	1:2 year	29	Required to activate and inundate upper zone (flood feature) riparian trees (*Trichilia emetica, Gymnosporia buxifolia*). The desktop estimation of 24.9 m^3/s will perform this function and is acceptable for riparian vegetation.	No morphological indicator; mobilises very fine to small gravel on the channel bed, limited mobilisation of medium gravel.
5	1:5 year	83	Required to activate terrestrial and alien woody species (such as *Vachellia gerrardii* and *V. robusta*) to prevent terrestrialisation of the riparian zone and encroachment of alien invasive species into the lower sub-zones. The desktop estimation of 48.7 m^3/s will only partly achieve this function.	No morphological indicator; mobilises small gravel on the channel bed, limited mobilisation of medium gravel.

5.6 EWR NS1 RECOMMENDATIONS FOR A C ECOLOGICAL CATEGORY

The flow requirements are summarised in **Table 5.6** to **5.8**. **The low flow EWR** is 4.7 MCM and equates to 17.4% of the nMAR. The **Total flow EWR** is 6.85 MCM which equates to 21.9% of the nMAR. The text in red on the flow duration tables refers to the wettest (April) and driest (August) months.

Table 5.6 Final high flow requirements

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	2.006	33	4	0.098
2	Annual	5.007	33	3	0.245
3	Annual	8.031	37	1	0.442
4	1:2 year	29.115	45	1	1.955
5	1:5 year	83.297	57	1	7.113

Table 5.7 Low flow assurance rules (m^3/s)

m^3/s	10	20	30	40	50	60	70	80	90	99
Oct	0.24	0.24	0.19	0.17	0.14	0.13	0.12	0.09	0.07	0.05
Nov	0.24	0.24	0.19	0.18	0.15	0.14	0.12	0.09	0.07	0.06
Dec	0.24	0.24	0.19	0.17	0.15	0.14	0.12	0.09	0.06	0.06
Jan	0.24	0.23	0.19	0.16	0.14	0.14	0.13	0.09	0.07	0.06
Feb	0.23	0.23	0.17	0.15	0.15	0.14	0.12	0.09	0.07	0.06
Mar	0.24	0.23	0.19	0.18	0.15	0.15	0.13	0.10	0.08	0.07
Apr[1]	0.25	0.23	0.22	0.20	0.18	0.16	0.14	0.12	0.10	0.08
May	0.23	0.23	0.19	0.17	0.15	0.15	0.12	0.09	0.07	0.06
Jun	0.23	0.23	0.19	0.16	0.16	0.14	0.12	0.10	0.08	0.06
Jul	0.24	0.23	0.19	0.15	0.15	0.14	0.12	0.10	0.07	0.06
Aug[1]	0.14	0.13	0.13	0.12	0.11	0.10	0.08	0.06	0.04	0.03
Sep	0.24	0.23	0.18	0.14	0.14	0.12	0.12	0.09	0.06	0.06

[1] The low flows for the 60th and 90th percentiles for the wettest (April) and driest (August) month.

Table 5.8 Total assurance rules (MCM)

MCM	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.034	0.884	0.612	0.511	0.371	0.36	0.32	0.232	0.178	0.143
Nov	1.077	0.873	0.593	0.553	0.459	0.367	0.306	0.228	0.177	0.148
Dec	1.056	0.892	0.608	0.546	0.398	0.386	0.316	0.241	0.174	0.154
Jan	0.875	0.834	0.599	0.44	0.388	0.384	0.336	0.236	0.183	0.154
Feb	0.825	0.805	0.524	0.471	0.372	0.342	0.297	0.216	0.161	0.149
Mar	1.078	0.871	0.666	0.582	0.494	0.389	0.335	0.277	0.211	0.187
Apr	0.94	0.852	0.665	0.616	0.568	0.418	0.362	0.308	0.255	0.217
May	0.988	0.862	0.61	0.566	0.492	0.395	0.323	0.25	0.188	0.174
Jun	0.847	0.844	0.595	0.51	0.41	0.363	0.314	0.249	0.199	0.163
Jul	0.875	0.872	0.618	0.505	0.406	0.377	0.319	0.255	0.183	0.153
Aug	0.607	0.584	0.442	0.359	0.304	0.269	0.215	0.152	0.112	0.084
Sep	0.857	0.754	0.572	0.396	0.364	0.311	0.311	0.227	0.165	0.163

6 EWR WM1: WHITE MFOLOZI RIVER

6.1 PRESENT ECOLOGICAL STATE

The PES for each component as well as for the EcoStatus are summarised in **Table 6.1** below.

Table 6.1 Present Ecological State results and comments

Component	PES	Comment
Instream IHI	**B/C (79.3%)**	The dominant impacts if on bed modification based on increase sedimentation (catchment use) and benthic growth. These are therefore non-flow related. **Confidence 3.3**
Riparian IHI	**B/C (77.4%)**	The key impacts are non-flow related and is based on bank structure changes in the non-marginal zone as well as longitudinal and lateral connectivity issues based on presence of alien vegetation. **Confidence 3**
Water quality	**B (84.5%)**	This EWR site is situated in an area of largely natural vegetation. Extensive subsistence farming is evident upstream of the site, which may result in turbidity impacts due to highly erodible soils. Water quality state is driven by turbidity values, with a small increase in nutrients. Integrated category is a B vs. the A/B from the 2014 assessment (88.57% vs 84.5% in 2022). **Confidence: 3** Diatoms indicate Good water quality.
Geomorphology	**B/C (78.8%)**	Increased hillslope-channel connectivity and sediment supply due to erosion in subsistence farming areas on highly erodible soils. Dam in middle catchment would have a small impact. Variable extent of sand patches in run habitat on the transect, probably relate to most recent flood event. Estimate slightly higher than in 2014 (77%) due to reduced extent of sand visible on channel bed. **Confidence: 3.7**
Riparian vegetation	**B/C (81.3)**	The marginal zone was scoured from recent floods at the time of the assessment. The zone was dominated by non-woody species, mostly sedges and grasses, but was mostly open cobble. Cattle on site indicate that grazing takes place but the site is remote within a gorge. The lower zone was dominated by non-woody vegetation with scattered woody individuals and alien cover low (<10%). Vegetation had been recently scoured from floods. Dominant species similar to the marginal zone (grasses and sedges) but with *Nuxia oppositifolia, S. cordatum, S. gueneense, F. sur* and *P. reclinata*. *B. salicina* was absent. The upper zone was similar to the lower zone. The MCB was dominated by woody vegetation or open bedrock and is within a gorge environment with a cliff and bedrock. *Spirostachys africana* was absent. **Confidence: 3.2**
Fish	**C (73.1%)**	Based on available information it is estimated that 18 fish species are expected in this reach under reference conditions (2022 update). Four species were collected during the course of the July 2014 survey, while four species were also sampled in 2022. It is estimated that all fish species may still be present under current conditions at reduced abundance and Frequency of Occurrence (FROC). The FRAI was amended for the purpose of the 2022 study with a score of 73.1% (Category C) calculated. The primary impacts responsible for the current state of the fish assemblage include altered water quality (nutrients, turbidity), bed modification (sedimentation) and flow alterations. **Confidence: 3**
Macro-invertebrates	**B/C (81.1%)**	The presence of seven taxa with a preference for moderately fast flowing water and an abundance of stones-in-current habitat, indicate favourable conditions at this site. Three taxa with a moderate requirement for unmodified physico-chemical conditions are also present and which added to the favourable MIRAI score. **Confidence: 3**
Instream	**C (77.08%)**	The Instream PES was derived using the EcoStatus model.
EcoStatus	**B/C (79.2%)**	The EcoStatus EC was derived using the EcoStatus model.

Table 6.2 Present Ecological State: Key flow and non-flow related impacts

Component	Causes	Sources	Flow or non-flow related
Water quality	Elevated turbidities; small increase in nutrient levels.	Sedimentation (and a small nutrient elevation) from extensive settlements and related activities.	Non-flow
Geomorphology	Increased sand deposits.	Catchment erosion.	Non-flow
Riparian vegetation	Altered species composition.	Alien plant species (perennial and invasive), including *Sesbanea,* although density was low.	Non-flow
Fish	Reduced habitat/flows, sedimentation of bottom substrates and water quality deterioration (nutrients, turbidity).	Water abstraction, dams, irrigation, catchment erosion, subsistence farming.	Non-flow
Macroinvertebrates	Sensitive taxa impacted by: reduced water availability; deteriorating water quality parameters (increased nutrients and salinity), as well as siltation.	Irrigation agriculture, mines, afforestation, settlements and towns use water. Trampling and grazing result in erosion.	Flow and non-flow

In summary, the B/C EcoStatus represents the response of the biota to largely non-flow related impacts such as overgrazing, erosion, the presence of alien vegetation.

6.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS evaluation resulted in a **MODERATE** importance. The highest scoring metrics were:

- Rare and endangered fish species.
- Diversity of instream habitat types.
- Rare and endangered riparian and wetland biota and biomes.
- Riparian / wetland species/taxon richness.
- Riparian migration corridor.

6.3 RECOMMENDED ECOLOGICAL CATEGORY (REC)

Due to the MODERATE importance, the REC is set to maintain the PES, i.e. a **B/C EC**.

6.4 LOW FLOW ECOLOGICAL WATER REQUIREMENTS

The low flow requirements as an initial estimate from the RDRM model was provided to specialists for a review and are summarised in Table 6.3.

Table 6.3 Low flow EWR review and recommendations: B/C PES

Month	Percentile	Discharge not constrained to PD (m^3/s)	Review	Recommended discharge (m^3/s)	Final discharge (m^3/s)
Sep	90th	0.775	**FISH:** Stress of approx.: 6.5. Some FS, FI and FD available for flow indicators spp. (*Amphilius uranoscopus* and *Labeobarbus natalensis*). Max depth approx. 0.55 m adequate (*Amphilius uranoscopus*) and max velocity (approx. 0.4 m/s) exceeds threshold (>0.3 m/s) for survival (*Amphilius uranoscopus*) and meets optimal velocity of *Amphilius uranoscopus* (0.4 to 0.8 m/s). Flow adequate to maintain water quality (oxygenation and temp). Min recommended flow to maintain fish in PES (C) = 0.775 m^3/s. **INVERTS:** At this discharge, there will be 5% FS/FI habitat available, as well as 3% FD. The following indicators for fast flows were assessed for WM1: Cobble dwellers with a preference for fast flows, Palaemonidae and Hydropsychidae (>0.6 m/s); and highly sensitive Heptageniidae in moderate flows (0.3 – 0.6 m/s). These flows will be adequate to allow these sensitive taxa to survive a stress level of 6.5.	0.775	0.773
Sep	60th	1.046	**FISH:** Stress of approx.: 5.5. Adequate FS, FI and FD available for survival of flow indicators spp. (*Amphilius uranoscopus* and *Labeobarbus natalensis*). Max depth approx. 0.58 m adequate for *Amphilius uranoscopus* and *Labeobarbus natalensis*, max velocity (approx. 0.5 m/s) exceeds threshold (>0.3 m/s) for survival (*Amphilius uranoscopus*) and suitable habitat for *Labeobarbus natalensis* (juveniles and adults). Flow adequate to maintain water quality (oxygenation and temp). Min recommended flow to maintain fish in PES (C) = 1.0 m^3/s. This flow will still maintain adequate FS, FI and FD, depth, velocity and water quality for indicator spp. during dry season. Min recommended flow to maintain fish in PES (C) = 1.0 m^3/s. Adequate habitats will be maintained for flow indicator spp. in the dry season. **INVERTS:** At this discharge, there will be 7% FS/FI habitat available, as well as 5% FD. These flows will result in adequate fast flowing habitat as well as supporting most of the associated biotopes at a stress level of 5.5. Flows and habitat for Palaemonidae and Hydropsychidae (>0.6 m/s) and Heptageniidae (0.3 – 0.6 m/s) will allow for local migration and extending habitat.	1.000	1.001
Feb	90th	1.424	**FISH:** Stress approx. 5.5. Adequate FS, FI and FD, max depth (0.60 m) and max velocity (0.64 m/s) available for indicator spp. (*Amphilius uranoscopus* and *Labeobarbus natalensis*) to maintain water quality and provide habitat for feeding and breeding. Min. recommended flow to maintain fish in PES (C) = 1.3 m^3/s. Adequate habitats will be maintained for flow indicator spp. **INVERTS:** At this discharge, there will be 10% FS/FI habitat available, as well as 8% FD. These flows will result in adequate fast and deep flowing habitat available for species to migrate and populate the added habitats. The higher water levels will support most of the local aquatic biotopes, especially that of inundated marginal vegetation habitats at this	1.300	1.262

Month	Percentile	Discharge not constrained to PD (m^3/s)	Review	Recommended discharge (m^3/s)	Final discharge (m^3/s)
			stress level of 5.5. Flows and habitat for Palaemonidae and Hydropsychidae (flows of >0.6 m/s) and Heptageniidae (flows of 0.3 – 0.6 m/s) will allow for wider migration for the Palaemonidae and extending habitat for the other sensitive species.		
Feb	60th	2.319	**FISH:** Stress of 4. Adequate FS, FI and FD, max depth (0.65 m) and max velocity (0.85 m/s) available for indicator spp. (*Amphilius uranoscopus* and *Labeobarbus natalensis*) to maintain water quality and provide adequate habitat for feeding and breeding. Min. recommended flow to maintain fish in PES (C) = 2.0 m^3/s. Adequate habitat (FS, FI, FD), velocities, depth and water quality will be maintained for flow indicator spp. **INVERTS:** At this discharge, there will be 36% of the aquatic biotopes consists of fast flows. The higher water levels will support most of the local aquatic biotopes and movement between habitats, especially that of inundated marginal vegetation habitats. Flows and habitat for sensitive species will allow for wider migration for the Palaemonidae and extending habitat for the other sensitive species at this stress level of 4.	2.000	1.979

6.5 HIGH FLOW EWR

The high flow EWR as output from the RDRM model was provided to specialists for review (**Table 6.4**).

Table 6.4 Desktop EWR high flow recommendations

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	15.083	68	4	1.558
2	Annual	32.749	68	3	3.383
3	Annual	90.492	72	1	9.899
4	1:2 year	191.344	80	1	23.256
5	1:5 year	580.150	92	1	81.089

Adjustments to the high flow EWR are indicated and motivated in **Table 6.5**.

Table 6.5 Desktop EWR high flow recommendations

Class	Frequency	Peak (m^3/s)	Vegetation Motivation	Geomorphology Motivation
1	Annual	10 - 15	Required to activate and inundate a proportion of marginal and lower zone graminoids (*Arundinella nepalensis, Cyperus longus, Juncus effusus, Miscanthus junceus*). The desktop estimation of 15 is acceptable for riparian vegetation.	Flow reaches the edge of the low flow channel; velocity sufficient to initiate movement of very fine gravels with limited movement of small to medium gravels.
2	Annual	24	Required to activate and inundate a proportion of marginal zone riparian trees (*Salix mucronata*, *Gomphostigma virgatum*). The desktop estimation of 32.7m^3/s is acceptable for riparian vegetation since this achieves the same function and inundates a slightly higher proportion of the indicator.	Flow extends in to rocky zone on right bank (RB) and over sandy cobble bar on LB; velocity sufficient to initiate movement of small gravel in main channel with limited movement of medium gravel.
3	Annual	60 - 80	Required to activate lower zone riparian trees (*Syzygium gueneense, Ficus sur, Nuxia oppositifolia*). The desktop estimation of 90.5 m^3/s will inundate 100% of the indicator which is acceptable for an annual flood for riparian vegetation.	Flows over top grassy bench on RB and extends over the edge of the flood bench on the LB; velocity sufficient to initiate movement of small gravel in main channel with limited movement of large gravel.
4	1:2 year	240	Required to activate and inundate proportion of upper zone (flood feature) riparian trees (*Syzygium cordatum*). The range for this indicator is from 150 - 360 and the 240 m^3/s inundates roughly 50% of the indicator. The desktop estimation of 191.3 m^3/s may suffice for riparian vegetation but is likely to be too low and some encroachment may result.	Flow extends to back of flood bench on LB, will provide potential for maintenance of bench through sediment deposition, flow level below that where there is a risk of erosion of high bank; velocity sufficient to initiate movement of small gravel in main channel with limited movement of small cobble, giving potential for releasing embedded coarse sediment.
5	1:5 year		No indicators to set flow. RDRM flow accepted.	

6.6 EWR WM1 RECOMMENDATIONS FOR A B/C ECOLOGICAL CATEGORY

The flow requirements are summarised in **Table 6.6** to **6.8**. **The low flow EWR** is 54.741 MCM and equates to 26.6% of the nMAR. The **Total flow EWR** is 89.314 MCM which equates to 40.1% of the nMAR. The text in red on the flow duration tables refers to the wettest (February) and driest (September) months.

Table 6.6 Final high flow requirements

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	10.063	65	4	0.982
2	Annual	24.437	68	3	2.525
3	Annual	60.377	72	1	6.604
4	1:2 year	242.909	84	1	31.000
5	1:5 year	582.74	92	1	81.451

Table 6.7 Low flow assurance rules (m^3/s)

m^3/s	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.919	1.595	1.542	1.407	1.292	1.101	0.974	0.903	0.833	0.721
Nov	2.826	2.098	1.838	1.690	1.551	1.396	1.178	1.032	0.938	0.706
Dec	3.106	2.849	2.267	1.915	1.794	1.569	1.365	1.206	1.063	0.902
Jan	3.074	2.947	2.599	2.264	2.070	1.879	1.552	1.324	1.167	0.918
Feb[1]	3.247	3.073	2.825	2.539	2.257	1.979	1.699	1.439	1.262	0.942
Mar	3.106	3.094	2.816	2.531	2.433	2.091	1.804	1.576	1.446	0.933
Apr	2.805	2.801	2.631	2.324	2.263	2.029	1.743	1.464	1.385	1.181
May	2.626	2.491	2.288	2.101	2.056	1.813	1.561	1.324	1.140	0.941
Jun	2.312	1.967	1.855	1.721	1.677	1.523	1.270	1.098	1.011	0.833
Jul	1.962	1.759	1.673	1.510	1.378	1.262	1.132	1.001	0.952	0.758
Aug	1.671	1.505	1.415	1.258	1.165	1.090	1.016	0.938	0.844	0.724
Sep[1]	1.591	1.453	1.324	1.212	1.105	1.001	0.916	0.839	0.773	0.640

[1] The low flows for the 60th and 90th percentiles for the wettest (February) and driest (September) month.

Table 6.8 Total assurance rules (MCM)

MCM	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	7.664	5.253	5.111	4.751	3.46	2.95	2.609	2.418	2.23	1.93
Nov	13.93	8.946	7.29	6.905	5.003	4.601	4.036	2.675	2.43	1.83
Dec	21.376	14.234	8.596	7.655	7.331	5.846	4.639	4.211	2.848	2.415
Jan	18.344	14.496	10.467	8.589	8.07	7.348	5.14	4.378	3.125	2.46
Feb	36.157	16.069	11.703	8.722	8.034	5.813	5.129	4.494	3.081	2.3
Mar	15.323	10.812	10.067	9.303	8.481	6.583	5.815	4.222	3.874	2.5
Apr	9.796	9.784	8.662	7.007	6.848	5.777	4.519	3.795	3.591	3.06
May	8.016	7.182	6.129	5.626	5.508	4.857	4.181	3.545	3.054	2.52
Jun	5.992	5.099	4.808	4.462	4.347	3.947	3.291	2.847	2.62	2.16
Jul	5.256	4.71	4.481	4.045	3.69	3.38	3.033	2.682	2.55	2.03
Aug	4.475	4.032	3.789	3.37	3.12	2.92	2.721	2.512	2.26	1.94
Sep	5.107	3.765	3.432	3.142	2.863	2.594	2.375	2.175	2.004	1.66

7 EWR BM1: BLACK MFOLOZI RIVER

7.1 PRESENT ECOLOGICAL STATE

The PES for each component as well as for the EcoStatus are summarised in **Table 7.1** below.

Table 7.1 Present Ecological State results and comments

Component	PES	Comment
Instream IHI	**B/C (77.7%)**	The major impact is on bank modification and connectivity issues which are non-flow related. **Confidence: 3.3**
Riparian IHI	**C (74.4%)**	Impacts are related to non-marginal substrate exposure and invasive alien vegetation. **Confidence: 3**
Water quality	**B/C (81.8%)**	Upstream activities include forestry, conservation and some coal mining. There is some localised erosion close to the site. Intermittent elevated sulphates. Integrated category has changed to a B/C as compared to the 2014 assessment of a B category (87.14% vs 81.8% in 2022). **Confidence: 3**. Diatoms indicate Very Good water quality.
Geomorphology	**A (93.0%)**	Localised erosion close to the site; local forestry; generally low impact. Possible increased sand deposition on RB flood bench raising channel bank since 2013. Represents a small shift in category from 2014 from A/B to A. **Confidence: 3.12**
Riparian vegetation	**C (74.9%)**	The marginal zone was dominated by non-woody vegetation, but *Salix mucronata* was expected and appeared missing. Reeds dominated pools and quiet areas, while sedges and grasses dominated elsewhere. Sedge and grass clumps also occurred instream and were associated with cobble outcrops. *Breonadia salicina* was also absent. The lower zone was dominated by non-woody vegetation, mainly grasses and sedges with some reeds near pools areas. All woody individuals were small, damaged or stunted and mostly alien. *Sesbanea* and *Lantana* cover was up to 20% in places and many weed species were present. *Syzygium guineense* and *Combretum erythrophyllum* were absent, although the latter was present in the upper zone. Grazing pressure and plant harvesting was high. The upper zone was dominated by non-woody vegetation, but wood remnants were visible. The prevalence of terrestrial woody (such as *D. cinerea* and *Vachellia sieberiana*) and alien (*Sesbanea*, *Lantana* and *Melia azedrach*) species was high. Harvesting and overgrazing occurred. Bedrock features were mostly clear of vegetation. Few individuals of *F. sycomorus, S. cordatum* and *C. erythrophyllum* existed and *S. guineense* was absent. The MCB was dominated by thick and encroached woody vegetation, mainly terrestrial species. Dominant species were *C. erythrophyllum* and V. *sieberiana* and *S. africana* was absent. The RB comprised alluvium while the LB consisted predominantly of bedrock. **Confidence: 3.2**
Fish	**C (75.9%)**	Based on available information it is estimated that 18 fish species are expected in this reach under reference conditions (2022 update). Five species were collected during the course of the July 2014 survey, while six species were also sampled in 2022. It is estimated that all fish species may still be present under current conditions at reduced abundance and FROC. The FRAI was amended for the purpose of the 2022 study with a score of 75.9% (Category C) calculated. The primary impacts responsible for the current state of the fish assemblage include altered water quality (mining, nutrients, salinity), slight bed modification (sedimentation). **Confidence: 3**
Macro-invertebrates	**B/C (81.2%)**	The presence of ten taxa with a preference for moderately fast flowing water and an abundance of stones-in-current habitat, indicate favourable conditions at this site. Five taxa with a moderate requirement for unmodified physico-chemical conditions are also present and which added to the favourable MIRAI score. **Confidence: 3**
Instream	**B/C (78.9%)**	The Instream PES was derived using the EcoStatus model.
EcoStatus	**C (76.9%)**	The EcoStatus EC was derived using the EcoStatus model.

Table 7.2 Present Ecological State: Key flow and non-flow related impacts

Component	Causes	Sources	Flow or non-flow related
Water quality	Elevated intermittent sulphates and salts.	Intermittent elevated sulphates from upstream mining activities.	Non-flow
Geomorphology	Possible increase in height of right flood bench.	Catchment erosion and/or increased magnitude of flood peaks.	Flow and non-flow
Riparian vegetation	Altered species composition.	Alien plant species (perennial and invasive, including *Sesbanea,* and *Lantana*).	Non-flow
	Vegetation removal.	Overgrazing by livestock.	Non-flow
	Vegetation removal.	Wood removal and collection.	Non-flow
Fish	Reduced water quality, slightly reduced bottom substrates.	Mining, catchment erosion.	Non-flow
Macroinvertebrates	Sensitive taxa impacted by deteriorating water quality parameters (increased nutrients, sulphides and salinity). Siltation.	Mining in catchment. Catchment erosion due to vegetation removal for sugarcane, roads and rural homesteads.	Non-flow

In summary, the C EcoStatus represents the response of the biota to largely non-flow related causes and sources such as intermittent elevated sulphates from mining activities, catchment erosion, alien plant species, overgrazing, catchment erosion and mining activities.

7.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS evaluation resulted in a **MODERATE** importance. The highest scoring metrics were:

- Rare and endangered fish species.
- Rare and endangered riparian and wetland biota and biomes.
- Riparian / wetland species/taxon richness.

7.3 RECOMMENDED ECOLOGICAL CATEGORY (REC)

Due to the moderate importance, the REC is set to maintain the PES of a **C EC**.

7.4 LOW FLOW ECOLOGICAL WATER REQUIREMENTS

The low flow requirements as an initial estimate from the RDRM model was provided to specialists for a review and are summarised in Table 7.3.

Table 7.3 Low flow EWR review and recommendations: C PES

Month	Percentile	RDRM Discharge m^3/s	Review	Recommended discharge (m^3/s)	Final discharge (m^3/s)
July	90th	0.360	**FISH:** Stress of 4. More than adequate fast habitats (FD: 7%, FI: 4% and FS: 12%), maximum depth (0.36 m) to maintain habitat and water quality for flow sensitive indicator species (*Amphilius uranoscopus*, *Enteromius eutaenia*, *Labeobarbus natalensis*, *Labeo molybdinus*). Minimum recommended discharge that should be able to maintain fish PES of C is 0.2 m^3/s. Under this flow adequate fast habitats will still be available to maintain habitat and water quality for most intolerant indicator species. **INVERTS:** At this discharge, there will be 16% FS/FI habitat available, as well as 7% FD. The following indicators for fast flows were assessed for BM1: Cobble dwellers with a preference for fast flows, Palaemonidae, Perlidae and Hydropsychidae (>0.6 m/s); and highly sensitive Heptageniidae in moderate flows (0.3 – 0.6 m/s). These flows will be adequate to allow these sensitive taxa to survive a stress level of 4. The sensitive Atyidae is a vegetation dweller and an indicator for inundated marginal vegetation habitats. The flow in the system will create some habitat for this taxon. Reduced flows recommended for fish adequate to maintain invertebrate PES.	0.200	0.200
July	60th	0.670	**FISH:** Stress of 2.8. More than adequate fast habitats (FD: 13%, FI: 15% and FS: 13%), maximum depth (0.42 m) to supply habitat and water quality for flow sensitive indicator species (*Amphilius uranoscopus*, *Enteromius eutaenia*, *Labeobarbus natalensis*, *Labeo molybdinus*). Minimum recommended discharge that should be able to maintain fish PES of C is 0.4 m^3/s. Under this flow adequate fast habitats (FD, FI and FS) will still be present in the dry season to maintain habitat and water quality for flow intolerant species. **INVERTS:** At this discharge, there will be 28% FS/FI habitat available, as well as 13% FD. These flows will result in adequate fast flowing habitat as well as supporting most of the associated biotopes at a stress level of 2.8. Flows and habitat for Palaemonidae, Perlidae and Hydropsychidae (>0.6 m/s) and Heptageniidae (0.3 – 0.6 m/s) will allow for local migration and extending habitat. The sensitive Atyidae is a vegetation dweller and an indicator for inundated marginal vegetation habitats. The flow in the system will create ample habitat for this taxon. Reduced flows recommended for fish adequate to maintain invertebrate PES.	0.400	0.390
Feb	90th	0.590	**FISH:** Stress of 5.8. More than adequate fast habitats (FD: 12%, FI: 7% and FS: 17%), maximum depth (0.4 m) to provide habitat and water quality for all life stages of flow sensitive indicator species (*Amphilius uranoscopus*, *Enteromius eutaenia*, *Labeobarbus natalensis*, *Labeo molybdinus*). Minimum recommended discharge that should be able to maintain fish PES of C in wet season (drought) is 0.4 m^3/s. Under this discharge adequate fast habitats will still be	0.400	0.400

Month	Percentile	RDRM Discharge m^3/s	Review	Recommended discharge (m^3/s)	Final discharge (m^3/s)
			available to maintain habitat, water quality and migratory depth for intolerant indicator species while adequate marginal habitats should still be available. **INVERTS:** At this discharge, there will be 24% FS/FI habitat available, as well as 12% FD. These flows will result in adequate fast and deep flowing habitat available for species to migrate and populate the added habitats. The higher water levels will support most of the local aquatic biotopes, especially that of inundated marginal vegetation habitats at this stress level of 5.8. The sensitive Atyidae is a vegetation dweller and an indicator for inundated marginal vegetation habitats. The flow in the system will create ample habitat for this taxon. Flows and habitat for Palaemonidae, Perlidae and Hydropsychidae (flows of >0.6 m/s) and Heptageniidae (flows of 0.3 – 0.6 m/s) will allow for wider migration for the Palaemonidae and extending habitat availability for the other sensitive species. Reduced flows recommended for fish adequate to maintain invertebrate PES.		
Feb	60th	0.980	**FISH:** Stress of 4.2. More than adequate fast habitats (FD: 17%, FI: 19% and FS: 12%), maximum depth (0.46 m) to provide habitat and water quality for all life stages of flow sensitive indicator species (*Amphilius uranoscopus*, *Enteromius eutaenia*, *Labeobarbus natalensis*, *Labeo molybdinus*). Minimum recommended discharge that should be able to maintain fish PES of C in wet season is 0.7 m^3/s. Under this discharge adequate fast habitats will still be available to maintain habitat, water quality and migratory depth for intolerant indicator species while adequate marginal habitats should still be available. **INVERTS:** At this discharge, there will be 48% of the aquatic biotopes consists of fast flows. The higher water levels will support most of the local aquatic biotopes and movement between habitats, especially that of inundated marginal vegetation habitats. The sensitive Atyidae is a vegetation dweller and an indicator for inundated marginal vegetation habitats. The flow in the system will create ample habitat for this taxon. Flows and habitat for sensitive species will allow for wider migration for the Palaemonidae, but it will also and extend habitat for the other sensitive species at this stress level of 4.2. Reduced flows recommended for fish adequate to maintain invertebrate PES.	0.700	0.700

7.5 HIGH FLOW EWR

The high flow EWR as output from the RDRM model was provided to specialists for review (**Table 7.4**).

Table 7.4 Desktop EWR high flow recommendations

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	14.840	61	4	1.357
2	Annual	32.243	68	3	3.331
3	Annual	51.928	72	1	5.680
4	1:2 year	75.303	80	1	9.152
5	1:5 year	143.209	92	1	20.017

Adjustments to the high flow EWR are indicated and motivated in **Table 7.5**.

Table 7.5 Desktop EWR high flow recommendations

Class	Frequency	Peak (m^3/s)	Vegetation Motivation	Geomorphology Motivation
1	Annual	11	Required to activate reeds and inundate marginal zone graminoids (*Ischaemum fasciculatum*, *Juncus effusus*). The desktop estimation of 14.8 m^3/s is acceptable for riparian vegetation.	Inundates marginal bench on LB, required for deposition of fine sediments to maintain bench; mobility of small to medium gravels on the channel bed.
2	Annual	22	Required to inundate marginal zone graminoids (*Ischaemum fasciculatum*, *Juncus effusus*) and flood about 50% of the reeds. The desktop estimation of 32.2 m^3/s is acceptable for riparian vegetation.	Fills low flow channel up to flood bench; mobility of small to medium gravels on the channel bed.
3	Annual	42	Required to inundate lower zone riparian trees (*Syzygium cordatum*) and the reed population (*Phragmites mauritianus*). The desktop estimation of 51.9 m^3/s is acceptable for riparian vegetation.	Inundates flood bench, required for deposition of fine sediments (sand) to maintain bench; mobility of small to medium gravels on the channel bed.
4	1:2 year	68	Required to activate base of the steeper bank where the shrub layer starts and inundates upper zone (grassed flood bench). The desktop estimation of 75.3 m^3/s will perform this function and is acceptable for riparian vegetation.	Reaches to base of LB macro-channel bank; mobility of small to medium gravels on the channel bed.
5	1:5 year	250	Required to activate terrestrial woody species (such as *Vachellia sieberiana*) to prevent terrestrialisation of the riparian zone. The desktop estimation of 143.2 m^3/s will only partly achieve this function.	Extends up MCB; high likelihood of bank erosion on unprotected banks; some cobbles mobilised on bed.

7.6 EWR BM1 RECOMMENDATIONS FOR A C ECOLOGICAL CATEGORY

The flow requirements are summarised in **Table 7.6** to **7.8**. **The low flow EWR** is 18.38 MCM and equates to 11% of the nMAR. The **Total flow EWR** is 43.58 MCM which equates to 26.1% of the nMAR. The text in red on the flow duration tables refers to the wettest (February) and driest (July) months.

Table 7.6 Final high flow requirements

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	11.172	61	4	1.022
2	Annual	22.108	65	3	2.156
3	Annual	42.351	72	1	4.633
4	1:2 year	68.275	76	1	7.883
5	1:5 year	251.252	104	1	39.699

Table 7.7 Low flow assurance rules (m^3/s)

m^3/s	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.62	0.44	0.40	0.39	0.37	0.31	0.24	0.19	0.19	0.17
Nov	1.11	0.78	0.67	0.61	0.52	0.42	0.31	0.24	0.19	0.14
Dec	1.26	0.99	0.89	0.79	0.68	0.55	0.41	0.31	0.22	0.19
Jan	1.46	1.43	1.09	0.87	0.79	0.65	0.49	0.37	0.32	0.25
Feb[1]	1.34	1.23	1.10	0.95	0.82	0.70	0.58	0.48	0.40	0.35
Mar	1.25	1.20	1.05	1.02	0.92	0.78	0.59	0.46	0.36	0.31
Apr	1.05	0.99	0.93	0.87	0.82	0.70	0.58	0.45	0.37	0.32
May	0.81	0.77	0.77	0.73	0.67	0.58	0.47	0.38	0.33	0.29
Jun	0.67	0.64	0.63	0.60	0.53	0.46	0.37	0.30	0.26	0.24
Jul[1]	0.60	0.58	0.56	0.52	0.46	0.39	0.31	0.24	0.20	0.17
Aug	0.40	0.40	0.39	0.37	0.35	0.31	0.26	0.22	0.20	0.20
Sep	0.41	0.37	0.35	0.34	0.32	0.28	0.21	0.18	0.18	0.15

[1] The low flows for the 60th and 90th percentiles for the wettest (February) and driest (July) month.

Table 7.8 Total assurance rules (MCM)

MCM	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	3.817	1.95	1.082	1.054	0.996	0.822	0.644	0.506	0.506	0.45
Nov	7.507	4.187	3.903	3.747	1.584	1.094	0.803	0.613	0.484	0.37
Dec	12.209	8.315	5.563	4.277	3.964	2.489	1.539	0.823	0.602	0.506
Jan	18.035	9.475	6.105	4.488	4.268	2.766	1.897	0.994	0.855	0.658
Feb	29.178	9.667	5.855	4.478	4.146	2.711	1.424	1.172	0.979	0.845
Mar	12.184	6.381	4.959	4.901	3.495	2.082	1.592	1.241	0.974	0.839
Apr	4.88	3.584	2.963	2.245	2.119	1.807	1.496	1.173	0.959	0.831
May	3.185	2.066	2.065	1.945	1.786	1.555	1.249	1.01	0.889	0.78
Jun	1.731	1.664	1.638	1.568	1.381	1.189	0.97	0.769	0.661	0.618
Jul	1.612	1.562	1.488	1.385	1.235	1.047	0.84	0.632	0.524	0.446
Aug	1.083	1.079	1.057	0.987	0.943	0.841	0.699	0.593	0.541	0.541
Sep	1.055	0.951	0.903	0.88	0.838	0.715	0.557	0.478	0.478	0.4

8 EWR MK1: MKUZE RIVER

8.1 PRESENT ECOLOGICAL STATE

The PES for each component as well as for the EcoStatus are summarised in **Table 8.1** below.

Table 8.1 Present Ecological State results and comments

Component	PES	Comment
Instream IHI	**C (66.3%)**	The C is a result of flow abstraction, nutrient, salts and toxic issues and sedimentation. **Confidence 3.5**
Riparian IHI	**C (72.1%)**	The C is a result of decreased flows, substrate exposure and alien vegetation. **Confidence 3**
Water quality	**C/D (58.3%)**	Impacts in the Mkuze River include forestry, coal mining in the upper catchment, dams (including an IBT from Pongolapoort Dam), rural areas, irrigated crops, alien vegetation, instream dams, erosion and sedimentation. The EWR site is downstream of the IBT, with extensive commercial agriculture and subsistence farming upstream of the site. Note that a water quality priority area was delineated in the SQR directly upstream of the reach containing the EWR site, i.e. SQ W31J-02469, with impacts being from the High Risk Mkuze Waste Water Treatment Works (WWTW). Integrated category has changed to a C/D as compared to the 2014 assessment of a D category, due to using the updated PAI table (58.1% vs 58.3% in 2022). **Confidence: 2.5**. Diatoms indicate Poor water quality.
Geomorphology	**B (82.26%)**	Widespread erosion in upper and middle catchment associated with rural settlements; extensive livestock grazing on RB. Possible loss of active floodplain channels. Flood zone subject to periodic sediment deposition and revegetation (Google Earth imagery). The estimated PES is considerably lower that from 2014 due to increased rating of catchment erosion and livestock disturbance. **Confidence: 2.7**
Riparian vegetation	**C (73%)**	The marginal zone was dominated by non-woody vegetation but with the presence of *Salix mucronata*. *Gomphostigma virgatum* was absent. It consisted of a narrow band of vegetation with both alluvium and cobble. Dominant species were *P. australis, I. fasiculatum, C. longus, P. senegalensis* and *S. mucronata*. *Cyperus marginatus* and *Breonadia salicina* were absent from the site. Some weed species occurred but in low abundance. The lower zone was similar to the marginal zone with the addition of a few species, notably *Cynodon dactylon* and *Cyperus dives*. Perennial alien cover was between 10 - 20%, mainly *Sesbanea punicea*. *Syzygium* and *B. salicina* were absent from the site. The upper zone consisted of mixed alluvium and cobble bars with mostly small woody vegetation displaying flood damage from recent floods. Alien invasion was high with up to 10% cover by *Sesbanea punicea* and *Lantana camara*. Non-woody ground cover was good. Some grazing occurred and some wood harvesting was evident. *Ziziphus mucronata* and *Vachellia karoo* were absent (may be an indication of harvesting). The bank was dominated by woody vegetation, mostly Senegalia *ataxycantha* and *Faurea saligna*. Cover of perennial aliens was around 20% with *M. azedarach, A. mearnsii* and *Eucalyptus* all present. Some erosion was evident and wood harvesting occurred. **Confidence: 3.2**
Fish	**C (75.4%)**	Based on available information it is estimated that 33 fish species are expected in this reach (instream and floodplain habitats) under reference conditions (2022 update). Four species were collected during the course of the July 2014 survey while five indigenous fish species were sampled in 2022. The river at the EWR site consisted of a sand bed with no rocks as cover, most fish utilizing the undercut bank, rootwads and overhanging vegetation as cover. It is estimated that all fish species may still be present under current conditions at reduced abundance and FROC. The FRAI was amended for the purpose of the 2022 study with a score of 75.4% (Category C) calculated. The primary impacts responsible for the current state of the fish assemblage include altered water quality (nutrients, organics, sulphates, salinity, pesticides) and slight bed modification (sedimentation). **Confidence: 3**
Macro-invertebrates	**C (77.7%)**	The presence of only two taxa with a preference for fast flowing water and the lack of a more diverse habitat, resulted in the “Moderately modified” MIRAI score. **Confidence: 3**
Instream	**C (76.6%)**	The Instream PES was derived using the EcoStatus model.

Component	PES	Comment
EcoStatus	C (74.8%)	The EcoStatus EC was derived using the EcoStatus model.

Table 8.2 Present Ecological State: Key flow and non-flow related impacts

Component	Causes	Sources	Flow or non-flow related
Water quality	Elevated intermittent sulphates and salts, presumably from upstream coal-mining. Toxics and elevated nutrients and turbidities.	Elevated salts, particularly sodium and sulphates from upstream mining activities. Nutrients and turbidity increases, and expected toxics due to upstream activities such as coal-mining, settlements, irrigated crops and High Risk Mkuze WWTW.	Non-flow
Geomorphology	Increased sediment load, bank destabilisation.	Catchment erosion; livestock grazing and trampling	Non-flow
Riparian vegetation	Altered species composition.	Alien plant species (perennial and invasive, including *Sesbanea, lantana* and *Mellia*).	Non-flow
	Reduced woody cover.	Targeted wood removal	Non-flow
Fish	Water quality deterioration and altered beds due to siltation.	Catchment erosion, mining, WWTW, over grazing, subsistence farming.	Non-flow
Macroinvertebrates	Sensitive taxa impacted by deteriorating water quality parameters (increased nutrients, sulphates and salinity), as well as siltation.	Catchment erosion from rural settlements and agricultural. Upstream WWTW, mining and sewage.	Non-flow

In summary, the C EcoStatus represents the response of the biota to largely non-flow related causes and sources coal mining, catchment erosion, alien vegetation and targeted vegetation removal.

8.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS evaluation resulted in a HIGH importance. The highest scoring metrics were:

- Rare and endangered fish species.
- Rare and endangered riparian and wetland biota and biomes.
- Riparian / wetland unique biota.
- Riparian / wetland species/taxon richness.
- Migration corridor for instream and riparian biota.
- The locality of the river within the Mkuze Game Reserve.

8.3 RECOMMENDED ECOLOGICAL CATEGORY (REC)

Due to the HIGH importance, the REC is set to maintain the improve the **PES of a C** to a B EC. Flows will only be set for a C however as this improvement must be achieved by addressing catchment issues rather than increased flows.

8.4 LOW FLOW ECOLOGICAL WATER REQUIREMENTS

The low flow requirements as an initial estimate from the RDRM model was provided to specialists for a review and are summarised in **Table 8.3**.

Table 8.3 Low flow EWR review and recommendations: C PES

Month	Percentile	Discharge m^3/s	Discharge not constrained to PD (m^3/s)	Review	Recommended discharge (m^3/s)	Final discharge (m^3/s)
Aug	90th	0.045	0.404	**FISH:** Stress of 8. Only fast habitat available is FVS (1%), max. depth of 0.27 m. Although no rheophilic species present, this flow will be essential to maintain adequate water quality (esp. oxygen and temperature) for semi-rheophilic species and those moderately intolerant to water quality deterioration. Maintaining adequate depth also essential for cover (as water column and to reach some overhang and undercut banks) for various species with requirement for this cover type. Flows lower than this may result in a decrease of the fish PES of C. **INVERTS:** At this discharge, there will be 1% FVS flowing habitats available at this site, mostly due to the shallow, alluvial sediment-dominated riverbed. The only rheophilic indicator invertebrate expected to require fast flows is Hydropsychidae (>0.6m/s). However, the lack of deeper cobble habitat will exclude them from this flow scenario. The low water levels will support 49% of the Shallow-Slow aquatic biotopes which will inundate some of the marginal vegetation habitats. The indicator for vegetation in slow flows are the Coenagrionidae, vegetation dwellers that survive in this inundated habitat. There is ample habitat for Gomphidae (shallow-slow, sandy habitats) and their numbers will be stable in habitats at the site with an 8.0 stress level.	0.404	0.400
Aug	60th	0.056	0.686	**FISH:** Stress of 6.8. Very limited FI (1%), FS (1%) and FVS (1%) available with max. depth of 0.3 m. Some fast habitats essential to maintain adequate depth and water quality (oxygenation) and also to reach banks to provide cover. Recommended minimum flow to maintain fish PES (C) is 0.65 m^3/s. A decrease lower than this will result in complete loss of FI habitats and potentially result in decreased water quality and cover that may not maintain PES. **INVERTS:** At this discharge, there will be an improvement in fast flows: 1% FVS, 1% FS, 1% FD flowing habitats available at this site, still influenced by the shallow, alluvial sediment-dominated riverbed. The only rheophilic indicator invertebrate expected to require fast flows, is Hydropsychidae (>0.6m/s). These water levels will support 60% of the SS aquatic biotopes which will inundate the marginal vegetation habitats. The indicator for vegetation in slow flows are the Coenagrionidae, vegetation dwellers that subsist in this inundated habitat. There is ample habitat for Gomphidae (shallow-slow, sandy habitats) and their numbers will increase in habitats at the site.	0.650	0.640
Feb	90th	0.053	0.480	**FISH:** Stress of 8. Only very limited fast habitat available FVS (1%) and FS (1%) (no FI or FD), max. depth of 0.28 m. Although no rheophilic species present, this flow will be essential to maintain adequate water quality (esp. oxygen and temperature) for semi-rheophilic species and those moderately intolerant to water quality deterioration. Maintaining adequate depth essential for cover (as water column and to reach some overhang and undercut banks)	0.480	0.480

Month	Percentile	Discharge m^3/s	Discharge not constrained to PD (m^3/s)	Review	Recommended discharge (m^3/s)	Final discharge (m^3/s)
				for various species with requirement for this cover type. Maintaining adequate depth also essential to allow migration (various large potadromous species present). Flows lower than this may result in a decrease of the fish PES of C. **INVERTS:** At this discharge, there will be 1% FVS and 1% FS habitats available at this site, mostly due to the shallow, alluvial sediment-dominated riverbed. The only rheophilic indicator invertebrate expected to require fast flows, is Hydropsychidae (>0.6m/s). However, the lack of deeper cobble habitat will exclude them from this flow scenario. The low water levels will support 55% of the SS aquatic biotopes which will inundate some of the marginal vegetation habitats. The indicator for vegetation in slow flows are the Coenagrionidae, vegetation dwellers that survive in this inundated habitat. There is ample habitat for Gomphidae (shallow-slow, sandy habitats) and their numbers will be stable in habitats at the site.		
Feb	60th	0.356	1.087	**FISH:** Stress of 6.5. Limited fast habitats available (FD: 1%, FI: 2% and FS: 3%), adequate max. depth (0.36 m). These habitats will be suitable to meet basic habitat requirements of all fish species during wet season (feeding, breeding, migration). Recommended minimum flow to maintain fish PES (C) is 0.9 m^3/s. Although this will result in loss of FD habitats, adequate FI habitats and maximum depth (>0.3 m) should be maintained to meet requirements for most species present (breeding, feeding, migration). **INVERTS:** At this discharge, there will be more habitats with fast flows available: 3% FS, 2% FI and 1% FD. The only rheophilic indicator invertebrate expected to require fast flows at the site, is low numbers of Hydropsychidae (>0.6m/s). With the increase in deeper habitat with fast flows, it will move into deeper site habitats with gravel or root wads. These water levels will support 93% of the SS aquatic biotopes which will create favourable inundated marginal vegetation habitats. Coenagrionidae, vegetation dwellers, will thrive in this inundated habitat. There is ample habitat for Gomphidae (shallow-slow, sandy habitats) and their numbers will increase in habitats at the site.	0.900	0.900

8.5 HIGH FLOW EWR

The high flow EWR as output from the RDRM model was provided to specialists for review (**Table 8.4**).

Table 8.4 Desktop EWR high flow recommendations

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	15.852	72	4	1.734
2	Annual	34.356	80	3	4.176
3	Annual	57.809	88	1	7.729
4	1:2 year	93.897	92	1	13.124
5	1:5 year	207.928	112	1	35.380

Adjustments to the high flow EWR are indicated and motivated in **Table 8.5**.

Table 8.5 Desktop EWR high flow recommendations

Class	Frequency	Peak (m^3/s)	Vegetation Motivation	Geomorphology Motivation
1	Annual	12 - 16	Required to activate and inundate a proportion of marginal and lower zone graminoids (*Phragmites mauritianus, Ischaemum fasciculatum*) and marginal zone trees (*Ficus caprefolia)*. The desktop estimation of 15.8m^3/s is acceptable for riparian vegetation.	Fills the low flow channel, activates sand bars, sands on bed mobile.
2	Annual	25 - 30	Required to inundate lower zone riparian trees (*F. sycomorus* saplings). The desktop estimation of 34.3 m^3/s is acceptable for riparian vegetation since this achieves the same function.	Overtops the marginal bench on LB promoting deposition of fine sediment; bed fully mobile (sand to very fine gravel.
3	Annual	40 - 60	Required to activate and inundate upper zone (flood feature) riparian trees (*Trichilia emetica*). The desktop estimation of 57.8 m^3/s will perform this function and is acceptable for an annual flood for riparian vegetation.	No geomorphological indicators.
4	1:2 year	90	Required to activate and inundate upper zone (flood feature) riparian trees (*Vachellia xanthophloea*, *V. gerrardii*). The desktop estimation of 93.8 m^3/s will perform this function and is acceptable riparian vegetation.	Overtops flood bench on left and right banks promoting deposition of sand.

Class	Frequency	Peak (m^3/s)	Vegetation Motivation	Geomorphology Motivation
5	1:5 year	180+	Required to activate floodplain and floodplain trees (*Ficus sycomorus).* The desktop estimation of 207.9 m^3/s will achieve this function and is acceptable for riparian vegetation.	No geomorphological indicators.
6	1:10 year	294+	This infrequent flood activates the largest of the floodplain trees and will provide recruiting opportunities for this community.	Overtops terrace on LB, sufficient flow to activate flood plain channels (these will be likely to receive flow from the main channel upstream).

8.6 EWR MK1 RECOMMENDATIONS FOR A C ECOLOGICAL CATEGORY

The flow requirements are summarised in **Table 8.6** to **8.8**. **The low flow EWR** is 34.74 MCM and equates to 21.9% of the nMAR. The **Total flow EWR** is 58.87 MCM which equates to 37.1% of the nMAR. The text in red on the flow duration tables refers to the wettest (February) and driest (August) months.

Table 8.6 Final high flow requirements

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	12.325	72	4	1.348
2	Annual	25.011	76	3	2.888
3	Annual	40.539	84	1	5.174
4	1:2 year	90.433	92	1	12.640
5	1:5 year	181.323	108	1	29.752

Table 8.7 Low flow assurance rules (m^3/s)

m^3/s	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.47	1.20	1.01	0.88	0.79	0.67	0.57	0.48	0.35	0.34
Nov	2.40	1.83	1.33	1.10	0.93	0.77	0.65	0.54	0.45	0.38
Dec	2.44	2.16	1.74	1.41	1.08	0.86	0.69	0.57	0.47	0.43
Jan	2.49	2.15	2.01	1.49	1.18	0.91	0.73	0.59	0.50	0.44
Feb[1]	2.53	2.23	1.86	1.52	1.19	0.90	0.72	0.58	0.48	0.39
Mar	2.57	2.25	2.25	1.98	1.54	1.12	0.80	0.74	0.59	0.45
Apr	2.35	2.03	1.76	1.50	1.16	0.91	0.72	0.59	0.48	0.47
May	1.86	1.67	1.47	1.27	1.07	0.84	0.69	0.58	0.45	0.42
Jun	1.60	1.43	1.21	1.05	0.89	0.73	0.60	0.51	0.43	0.40
Jul	1.39	1.31	1.06	0.90	0.80	0.68	0.58	0.50	0.42	0.40
Aug[1]	1.23	1.06	0.93	0.83	0.73	0.64	0.55	0.47	0.40	0.35
Sep	1.08	0.97	0.77	0.69	0.63	0.51	0.42	0.36	0.32	0.32

[1] The low flows for the 60th and 90th percentiles for the wettest (February) and driest (Aug) month.

Table 8.8 Total assurance rules (MCM)

MCM	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	6.81	4.555	2.699	2.351	2.106	1.79	1.527	1.291	0.944	0.904
Nov	16.293	7.637	6.338	4.187	3.764	2.9	1.678	1.398	1.162	0.981
Dec	17.49	12.316	8.909	6.67	4.248	3.645	1.843	1.533	1.261	1.14
Jan	18.968	11.338	8.907	6.89	4.504	3.793	1.942	1.583	1.334	1.168
Feb	26.837	13.912	8.709	6.606	4.242	3.326	1.747	1.424	1.175	0.963
Mar	13.4	10.27	8.922	7.962	5.465	3.606	2.145	1.982	1.577	1.202
Apr	8.969	6.61	5.423	3.886	3.012	2.353	1.878	1.532	1.238	1.22
May	4.971	4.477	3.937	3.404	2.854	2.257	1.857	1.542	1.212	1.113
Jun	4.151	3.703	3.129	2.723	2.305	1.899	1.564	1.33	1.105	1.042
Jul	3.724	3.509	2.844	2.416	2.137	1.821	1.558	1.336	1.116	1.065
Aug	3.285	2.84	2.492	2.212	1.96	1.716	1.477	1.252	1.075	0.939
Sep	2.809	2.503	1.999	1.787	1.635	1.322	1.081	0.928	0.831	0.82

9 EWR UP1: UPPER PONGOLA RIVER

9.1 PRESENT ECOLOGICAL STATE

The PES for each component as well as for the EcoStatus are summarised in **Table 9.1** below.

Table 9.1 Present Ecological State results and comments

Component	EC	Comment
Instream IHI	**B/C (80.5%)**	Impacts are small, largely non-flow related with catchment changes being the most dominant. **Confidence 3.5**
Riparian IHI	**B/C (77.8%)**	Dominant impacts are related to bank structure modification (substrate exposure and invasive alien vegetation. **Confidence 3**
Water quality	**A/B (88.3%)**	The EWR site is located in the upper portion of the Pongolo River close to the town of Frischgewaagd. The major land-use in the upper part of the catchment is forestry with commercial agriculture. There is also mining upstream of the EWR site, with sand-mining evident at the site. The river is large with good flows, which may buffer any impacts. Ecological Category is slightly better than the 2014 assessment (87.3%, B, vs 88.3% in 2022). **Confidence: 2.0 based on data availability for the assessment**. Diatoms indicate Very Good water quality.
Geomorphology	**A/B (89.8%)**	Upper catchment in good condition, extensive forestry throughout catchment but valley bottom wetlands appear to be intact, dense rural settlement with local gully erosion and moderate erosion potential on hillslopes in middle catchment. Significant local disturbance of RB by sand mining Instream and riparian habitat appears close to natural. PES slightly higher than the 2014 assessment (87%). **Confidence: 2.9**
Riparian vegetation	**C (70.0%)**	The marginal zone was dominated by non-woody vegetation but with the presence of *Salix mucronata*. *Gomphostigma virgatum* was absent. It consisted of a narrow band of vegetation with both alluvium and cobble. Dominant species were *P. australis, I. fasiculatum, C. longus, P. senegalensis* and *S. mucronata*. *Cyperus marginatus* and *Breonadia salicina* were absent from the site. Some weed species occurred but in low abundance. The lower zone was similar to the marginal zone with the addition of a few species, notably *Cynodon dactylon* and *Cyperus dives*. Perennial alien cover was between 10 - 20%, mainly *Sesbanea punicea*. *Syzygium* and *B. salicina* were absent from the site. The upper zone consisted of mixed alluvium and cobble bars with mostly small woody vegetation displaying flood damage from recent floods. Alien invasion was high with up to 10% cover by *Sesbanea punicea* and *Lantana camara*. Non-woody ground cover was good. Some grazing occurred and some wood harvesting was evident. *Ziziphus mucronata* and *Vachellia karoo* were absent (may be an indication of harvesting). The bank was dominated by woody vegetation, mostly Senegalia *ataxycantha* and *Faurea saligna*. Cover of perennial aliens was around 20% with *M. azedarach, A. mearnsii* and *Eucalyptus* all present. Some erosion was evident and wood harvesting occurred. **Confidence: 3.2**
Fish	**C (73.9%)**	Based on available information it is estimated that 26 fish species are expected in this reach under reference conditions (2022 update). Four species were collected during the course of the July 2014 survey while six indigenous fish species were sampled in 2022. It is estimated that all fish species may still be present under current conditions at reduced abundance and FROC. The FRAI was amended for the purpose of the 2022 study with a score of 73.9% (Category C) calculated. The primary impacts responsible for the current state of the fish assemblage include altered water quality (nutrients and slightly elevated salinity) and slight bed modification (sedimentation). **Confidence: 3**
Macro-invertebrates	**B/C (79.5%)**	The presence of ten taxa with a preference for moderately fast flowing water and an abundance of stones-in-current habitat, indicate favourable conditions at this site. Six taxa with a moderate requirement for unmodified physico-chemical conditions are also present and which added to the favourable MIRAI score. **Confidence: 3**
Instream	**C (77.0%)**	The Instream PES was derived using the EcoStatus model.
EcoStatus	**C (73.5%)**	The EcoStatus EC was derived using the EcoStatus model.

Table 9.2 Present Ecological State: Key flow and non-flow related impacts

Component	Causes	Sources	Flow or non-flow related
Water quality	Elevated turbidity.	Upstream cultivation and urban and rural settlements.	Non-flow
Geomorphology	Small increase in channel sediments.	Local catchment erosion.	Non-flow
Riparian vegetation	Altered species composition.	Alien plant species (perennial and invasive, including *Sesbanea, lantana* and *Mellia*).	Non-flow
	Reduced woody cover.	Targeted wood removal.	Non-flow
Fish	Water quality deterioration and altered rocky substrate condition (sedimentation).	Rural settlements, forestry, catchment erosion.	Non-flow
Macroinvertebrates	Sensitive taxa impacted by deteriorating water quality parameters (increased nutrients and salinity), as well as increased sedimentation.	Local sand mining. Numerous forestry roads, heavy grazing pressure and dense rural settlements - increased sediment yield and load.	Non-flow

In summary, the C EcoStatus represents the response of the biota to largely non-flow related causes and sources such as upstream cultivation and urbanisation, local catchment erosion, alien plant species, forestry, local sand mining.

9.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS evaluation resulted in a MODERATE importance. The highest scoring metrics were:

- Rare and endangered fish species.
- Biota intolerant to flow modification.
- Riparian / wetland unique biota.

9.3 RECOMMENDED ECOLOGICAL CATEGORY (REC)

Due to the moderate importance, the REC is set to maintain the PES of a **C EC**.

9.4 LOW FLOW ECOLOGICAL WATER REQUIREMENTS

The low flow requirements as an initial estimate from the RDRM model was provided to specialists for a review and are summarised in **Table 9.3.**

Table 9.3 Low flow EWR review and recommendations: C PES

Month	Percentile	RDRM Discharge m^3/s	Review	Recommended discharge (m^3/s)	Final discharge (m^3/s)
Sep	90th	0.120	**FISH:** Stress of 6.8. Some FS and very limited FI (< 2%) available (no FD). Max. depth: 0.21 m, max. velocity: 0.6 m/s. These flows thought to not be suitable to maintain flow sensitive fish (*Amphilius uranoscopus*, *Varicorhinus nelspruitensis*, *Opsaridium peringueyi*). Recommended to increase to 0.16 m^3/s to ensure adequate habitat and water quality (oxygen) for flow intolerant spp. (esp. to increase FI habitat). **INVERTS:** At this discharge, there will be 16% FS/FI habitat available, which is quite favourable to the sensitive macroinvertebrate assemblages. The following indicators for fast flows were assessed for WM1: Cobble dwellers with a preference for fast flows, Perlidae and Hydropsychidae (>0.6 m/s); and highly sensitive Heptageniidae in moderate flows (0.3 – 0.6 m/s). These flows will be adequate to allow for these sensitive taxa to survive a stress level of 6.8.	0.160	0.120
Sep	60th	0.500	**FISH:** Stress of 5. Some fast habitats (FS, FI, FD) available for flow sensitive indicator spp., adequate depth and velocity and water quality should be maintained (oxygenation). Recommended flow to maintain fish PES (C) is 0.5 m^3/s. **INVERTS:** At a discharge of 0.5 m^3/s, there will be 8% FS/FI habitat available, as well as 6% FD. These flows will result in adequate fast flowing habitat as well as supporting most of the associated biotopes at a stress level of 5.0. Flows and habitat for Perlidae and Hydropsychidae (>0.6 m/s); and highly sensitive Heptageniidae in moderate flows (0.3 – 0.6 m/s) will allow for local migration and extending habitat.	0.500	0.500
Feb	90th	1.460	**FISH:** Stress: 5.5. Adequate fast habitats (FS, FI, FD) available for flow sensitive indicator spp. (*Amphilius uranoscopus*, *Varicorhinus nelspruitensis*, *Opsaridium peringueyi*). The flows can be reduced to 1.2 m^3/s where adequate fast habitats will still be available and water quality will be maintained for flow dependant spp. **INVERTS:** At this discharge, there will be 28% FS/FI habitat available, as well as 9% FD. These flows will result in adequate fast and deep flowing habitat available for species to migrate and populate the added habitats. The higher water levels will support most of the local aquatic biotopes especially that of inundated marginal vegetation habitats at this stress level of 5.5. Flows and	1.200	1.190

Month	Percentile	RDRM Discharge m^3/s	Review	Recommended discharge (m^3/s)	Final discharge (m^3/s)
			habitat for Perlidae and Hydropsychidae (>0.6 m/s); and highly sensitive Heptageniidae in moderate flows (0.3 – 0.6 m/s) will allow for local migration and extending habitat.		
Feb	60th	2.800	**FISH:** Stress: 3. More than adequate fast habitats will be available to maintain flow dependants indicator spp. Decreasing the flow to 2.0 m^3/s will still provide adequate fast habitats and water quality to maintain the fish in PES of C. **INVERTS:** At this discharge, there will be 52% of the aquatic biotopes consists of fast flows. The higher water levels will support most of the local aquatic biotopes and movement between habitats, especially that of inundated marginal vegetation habitats (indicator: Coenagrionidae). Flows and habitat for sensitive species will allow for an increase of Perlidae and Hydropsychidae, thus extending their preferred habitat during a stress level of 4.	2.000	1.980

9.5 HIGH FLOW EWR

The high flow EWR as output from the RDRM model was provided to specialists for review (**Table 9.4**).

Table 9.4 Desktop EWR high flow recommendations

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	18.314	57	4	1.564
2	Annual	39.479	61	3	3.611
3	Annual	74.992	65	1	7.315
4	1:2 year	136.918	72	1	14.977
5	1:5 year	354.150	88	1	47.348

Adjustments to the high flow EWR are indicated and motivated in **Table 9.5**.

Table 9.5 Desktop EWR high flow recommendations

Class	Frequency	Peak (m^3/s)	Vegetation Motivation	Geomorphology Motivation
1	Annual	8 - 12	Required to activate and inundate a proportion of marginal and lower zone graminoids (*Phragmites australis, Cyperus longus, Ischaemum fasciculatum, Persicaria senegalensis, Cyperus digitatus, Arundinella nepalensis*). The desktop estimation of 18.3 m^3/s inundates 100% of the indicator but is acceptable for riparian vegetation.	Flow extends into edge of marginal zone where it can provide some fine sediment to maintain this zone. Entrainment of very fine gravels in channel bed, limited entrainment of small to medium gravel.
2	Annual	23 - 30	Required to activate and inundate a proportion of marginal zone riparian trees (*Salix mucronata*) and lower zone graminoids (*Miscanthus junceus*). The desktop estimation of 39.4 m^3/s is acceptable for riparian vegetation since this achieves the same function and inundates a slightly higher proportion of the indicator.	Flow extends into marginal zone where it can provide some fine sediment to maintain this zone . Entrainment of small gravels in channel bed, limited entrainment of medium gravel.
3	Annual	56	Not specified for vegetation, no adequate indicators.	Replenishes sand in the sand mining area. Entrainment of small gravels in channel bed, limited entrainment of small cobble allows some flushing of fines.
4	1:2 year	70 - 130	Required to activate and inundate a proportion of upper zone riparian trees (*Combretum erythrophyllum*). The desktop estimation of 136.9 m^3/s will perform this function and is acceptable for riparian vegetation.	Flow overtops flood bench; sand deposition to maintain bench. Entrainment of small gravels in channel bed, limited entrainment of small cobble to release fine sediment.
5	1:5 year	> 220	Required to activate terrestrial woody species (*Diospyro lyceoides*) to prevent terrestrialisation of the riparian zone. The range for this indicator is from 220 - 460. The desktop estimation of 354.1 m^3/s will achieve this function and is adequate for riparian vegetation.	Flow overtops high bench (terrace) below vertical bank (evidence of recent flooding at this hight). Entrainment of medium gravels in channel bed, limited entrainment of medium cobble. Flows sufficient to reset channel and activate bed to release fine sediment.

9.6 EWR UP1: RECOMMENDATIONS FOR A C ECOLOGICAL CATEGORY

The flow requirements are summarised in **Table 9.6** to **9.8**. **The low flow EWR** is 58.84 MCM and equates to 15.4% of the nMAR. The **Total flow EWR** is 97.31 MCM which equates to 27.3% of the nMAR. The text in red on the flow duration tables refers to the wettest (February) and driest (September) months.

Table 9.6 Final high flow requirements

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	8.237	84	4	1.051
2	Annual	23.241	88	3	3.107
3	Annual	56.520	96	1	8.243
4	1:2 year	70.101	100	1	10.650
5	1:5 year	222.272	120	1	40.523

Table 9.7 Low flow assurance rules (m^3/s)

m^3/s	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.27	2.11	1.63	1.23	0.95	0.69	0.50	0.41	0.35	0.10
Nov	3.04	2.97	2.46	1.88	1.46	1.09	0.81	0.63	0.55	0.45
Dec	3.34	3.05	2.72	2.36	1.94	1.55	1.22	0.94	0.79	0.64
Jan	3.18	2.89	2.60	2.42	2.16	2.03	1.64	1.25	0.99	0.83
Feb[1]	2.58	2.50	2.42	2.30	2.16	1.98	1.76	1.49	1.19	0.92
Mar	5.04	5.04	3.37	3.14	3.08	2.53	2.01	1.72	1.57	1.21
Apr	3.12	2.94	2.57	2.57	2.56	2.27	1.85	1.65	1.47	1.22
May	3.33	3.15	2.72	2.39	2.03	1.74	1.45	1.22	0.96	0.70
Jun	2.99	2.89	2.40	1.97	1.54	1.17	0.84	0.70	0.60	0.38
Jul	2.38	2.26	1.75	1.22	0.96	0.70	0.52	0.43	0.31	0.11
Aug	1.60	1.51	1.21	0.98	0.64	0.48	0.35	0.25	0.14	0.05
Sep[1]	1.90	1.58	1.25	0.96	0.70	0.50	0.34	0.21	0.12	0.03

[1] The low flows for the 60th and 90th percentiles for the wettest (February) and driest (September) month.

Table 9.8 Total assurance rules (MCM)

MCM	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	9.182	7.417	5.43	4.338	3.599	2.898	1.345	1.094	0.946	0.28
Nov	19.278	10.795	9.48	7.977	6.881	4.64	3.163	2.691	2.485	1.172
Dec	31.078	18.856	15.519	9.415	8.306	7.246	6.363	3.576	3.154	1.708
Jan	24.08	18.087	15.218	12.748	8.889	8.554	7.492	6.442	3.691	2.212
Feb	43.718	16.753	16.245	10.835	8.373	7.928	7.028	4.688	3.947	2.235
Mar	24.861	21.754	15.044	11.511	11.352	9.783	6.434	5.654	4.207	3.239
Apr	16.228	10.72	9.776	7.7	7.698	6.944	4.784	4.276	3.813	3.166
May	9.977	9.476	8.341	6.39	5.433	4.65	3.887	3.267	2.575	1.87
Jun	8.801	7.498	6.214	5.109	3.991	3.029	2.176	1.805	1.552	0.98
Jul	6.371	6.065	4.7	3.26	2.565	1.869	1.39	1.148	0.84	0.3
Aug	4.278	4.053	3.23	2.63	1.72	1.28	0.93	0.66	0.38	0.13
Sep	5.978	5.134	3.252	2.479	1.822	1.285	0.88	0.55	0.32	0.09

10 EWR AS1: ASSEGAAI RIVER

10.1 PRESENT ECOLOGICAL STATE

The PES for each component as well as for the EcoStatus are summarised in **Table 10.1** below.

Table 10.1 Present Ecological State results and comments

Component	PES	Comment
Instream IHI	**C/D (59.1%)**	Impacts are flow and non-flow related and equally spread over hydrology, physico-chemical, bank and connectivity metrics. **Confidence 3.3**
Riparian IHI	**C/D (58.7%)**	The dominant impacts are flow changes from the upstream Heyshope Dam and bank structure changes due to the presence of alien vegetation and substrate exposure. **Confidence 3**
Water quality	**B/C (80.6%)**	Commercial and subsistence agriculture takes place in the catchment around the Heyshope Dam with limited coal mining Integrated category has changed to a B/C as compared to the 2014 assessment of a B category (81.91% vs 80.6% in 2022). **Confidence: 3.5**. Diatoms indicate Good water quality.
Geomorphology	**C (70.84%)**	Major impact is the Heyshope Dam that has reduced flood flows as well as the MAR and will also have trapped sediment. This may have resulted in the lack of fine sediment on the flood benches that are dominated by boulders. Channel incision is evident in lower gradient reaches below the dam but not at the site due to the bedrock control. Extensive forestry in catchment below the dam but erosion risk low due to relatively flat terrain. Lateral silt deposits noted in 2014not evident in 2022.PES assessment higher than in 2014 (C 65%). **Confidence: 2.61**
Riparian vegetation	**C (69.9)%**	The marginal zone was dominated by a mixture of woody and non-woody vegetation, mostly dense; a likely response to flow regulation and reduced flooding disturbance (with Heyshope Dam upstream). Woody vegetation was dominated by *Salix mucronata* while non-woody vegetation was dominated by reeds, sedges and grasses. *Salix mucronata* provides good overhanging cover for instream fauna, as does *Ishaemum fasiculatum* which grows into the water. *Gomphostigma virgatum* was absent at the site, possibly due to competition (shading) from *S. mucronata*, again a likely response to flow regulation. The lower zone consisted mostly of dense non-woody vegetation but with a dense band of *S. mucronata* along the stream side. Species were similar to the marginal zone with the addition of *Cynodon dactylon*. *Syzygium* species were absent in the zone. The upper zone consisted of a floodplain area with several high flow channels and backwater areas. Vegetation comprised a mix of woody and non-woody vegetation but dominated by woody vegetation with different species from the marginal and lower zones: Dominant woody species were *Searsia gerarrdii* and *Combretum erythrophyllum*. Perennial alien species such as *Sesbanea punicea* and *Acacia mearnsii* were present but with low cover (5%) of the zone. The density of woody cover suggests the reduction of flooding disturbance in the flow regime. *Ziziphus mucronata* and *Syzygium* species were absent. The bank was dominated by woody vegetation, mostly thicket, with some open grassland in places. Perennial alien species had invaded the banks with up to 50% cover in places. Dominant species were *A. mearnsii, A. melanoxylon, A. caffra, Lantana camara* and *Diospyros lyceoides*. *Ziziphus mucronata* was absent. Some wood harvesting was prevalent **Confidence: 3.2**
Fish	**C (69.2%)**	Based on available information it is estimated that 19 fish species are expected in this reach under reference conditions (2022 update). Four species were collected during the course of the July 2014 survey with an initial FRAI of 81.8% (category B/C) calculated. Four species was also sampled at the site during IUCMA monitoring during 2019 and also indicated that the abundance of fish declines from the 2010 and 2015 surveys. A possible reason for the lower abundance of fish and species collected, could be related to reduced water quality (IUCMA, 2019). .Four indigenous fish species were also sampled during 2022. It is estimated that all fish species may still be present under current conditions at reduced abundance and FROC. The FRAI was amended for the purpose of the 2022 study with a score of 69.2% (Category C) calculated. Based on the latest information (2019 and 2022) it seems that biotic conditions have deteriorated slightly at the site since 2014. The primary impacts responsible for the current state of the fish assemblage include altered water quality (nutrients, salinity), slight bed modification (sedimentation), altered flows (upstream damming) and possibly also poaching with nets. **Confidence: 4**

Component	PES	Comment
Macro-invertebrates	**B/C (78.6%)**	The MIRAI score of 86.4% (B) during the 2014 EWR studies declined to a B/C (78.6%) during the later macroinvertebrate studies (IUCMA surveys of 2019). Several taxa recorded up- and downstream from the site during previous surveys, were absent during both the 2015 and 2019 surveys. **Confidence: 3**
Instream	**C (77.8%)**	The Instream PES was derived using the EcoStatus model.
EcoStatus	**C (74.16%)**	The EcoStatus EC was derived using the EcoStatus model.

Table 10.2 Present Ecological State: Key flow and non-flow related impacts

Component	Causes	Sources	Flow or non-flow related
Water quality	Elevated nutrient levels, with some evidence of toxics.	Upstream agricultural activities.	Non-flow
Geomorphology	Reduced coarse sediment. Reduced flood magnitude.	Heyshope Dam.	Flow
Riparian vegetation	Altered species composition.	Perennial alien species had invaded the banks with up to 50% cover in places. Dominant species were *A. mearnsii, A. melanoxylon,* and *Lantana camara.* Others included *Sesbanea punicea.*	Non-flow
	Increased woody and to some extent non-woody vegetation cover	Flow regulation and reduced flooding disturbance.	Flow
Fish	Altered water quality, habitat deterioration (sedimentation), flow modification and over-exploitation.	Towns/settlements, Water Treatment Works (WTW), Forestry, Dams (such as Heyshope), catchment erosion, poaching.	Flow and non-flow
Macroinvertebrates	Flow modifications and nutrient enrichments.	Nutrient enrichments from the upstream settlements and towns. Reduced floods due to the Heyshope Dam.	Flow and non-flow

In summary, the C EcoStatus represents the response of the biota to largely non-flow related causes and sources such as upstream agricultural activities, towns/settlements, Water Treatment Works (WTW), forestry and alien species. Flow related impacts is associated with reduced floods and in general flow modification from Heyshope Dam.

10.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS evaluation resulted in a MODERATE importance. The highest scoring metrics were:

- Rare and endangered fish species.
- Riparian / wetland unique biota.
- Riparian / wetland species/taxon richness.
- Migration corridor for instream and riparian biota.

10.3 RECOMMENDED ECOLOGICAL CATEGORY (REC)

Due to the moderate importance, the REC is set to maintain the PES of a **C EC**.

10.4 LOW FLOW ECOLOGICAL WATER REQUIREMENTS

The low flow requirements as an initial estimate from the RDRM model was provided to specialists for a review and are summarised in **Table 10.3**.

Table 10.3 Low flow EWR review and recommendations: C PES

Month	Percentile	RDRM Discharge m^3/s	Review	Recommended discharge (m^3/s)	Final discharge (m^3/s)
Sep	90th	0.334	**FISH:** Stress of 6. More than adequate fast habitats (FD: 3%, FI: 3% and FS: 12%) will be available to maintain habitat and water quality for rheophilic species (*Amphilius uranoscopus*, *Chiloglanis anoterus*, *Chiloglanis emarginatus*, *Chiloglanis swierstrai*, *Enteromius argenteus*, *Opsaridium peringueyi*) and various semi-rheophilic species (*Labeobarbus marequensis, Labeobarbus polylepis, Varicorhinus nelspruitensis* etc.). The minimum discharge recommended to maintain the PES is 0.2 m^3/s. Although FD habitats may be lost, adequate fast habitats (FI and FS), max. depth (>0.3 m) and water quality will be maintained to provide sufficient habitats for rheophilic and semi-rheophilic species. **INVERTS:** At this discharge, there will be 18% FS/FI to FD habitat available, which is favourable to the sensitive macroinvertebrate assemblages. The following indicators for fast flows were assessed for AS1: Cobble dwellers with a preference for fast flows, Perlidae and Hydropsychidae (>0.6 m/s); and highly sensitive Heptageniidae in moderate flows (0.3 – 0.6 m/s). These flows will be adequate to allow for these sensitive taxa to survive a stress level of 6.0. The sensitive Atyidae is a vegetation dweller and an indicator for inundated marginal vegetation habitats. The flow in the system will create ample habitat for this taxon.	0.200	0.200
Sep	60th	0.424	**FISH:** Stress of 5.3. More than adequate fast habitats (FD: 4%, FI: 4% and FS: 12%) will be available to maintain habitat and water quality for rheophilic species (*Amphilius uranoscopus*, *Chiloglanis anoterus*, *Chiloglanis emarginatus*, *Chiloglanis swierstrai*, *Enteromius argenteus*, *Opsaridium peringueyi*) and various semi-rheophilic species (*Labeobarbus marequensis, Labeobarbus polylepis, Varicorhinus nelspruitensis* etc.). The minimum discharge recommended to maintain PES is 0.3. Adequate fast habitats (FD, FI and FS), max. depth (>0.3 m) and water quality will be maintained to provide sufficient habitats for rheophilic and semi-rheophilic species. **INVERTS:** At this discharge, there will be 17% FS/FI to FD habitat available, which is favourable to the sensitive macroinvertebrate assemblages. The following indicators for fast flows were assessed for AS1: Cobble dwellers with a preference for fast flows, Perlidae and Hydropsychidae (>0.6 m/s); and highly sensitive Heptageniidae in moderate flows (0.3 – 0.6 m/s). These flows will be adequate to allow for these sensitive taxa to survive a stress level of 5.3. The sensitive Atyidae is a vegetation dweller and an indicator for inundated marginal vegetation habitats. The flow in the system will create ample habitat for this taxon.	0.300	0.300
Feb	90th	1.150	**FISH:** Stress of 6.8. More than adequate fast habitats (FD: 14%, FI: 20% and FS: 17%) will be available to provide habitat (feeding and breeding) and water quality for rheophilic species (*Amphilius uranoscopus*, *Chiloglanis anoterus*, *Chiloglanis*	0.700	0.690

Month	Percentile	RDRM Discharge m^3/s	Review	Recommended discharge (m^3/s)	Final discharge (m^3/s)
			emarginatus, *Chiloglanis swierstrai*, *Enteromius argenteus*, *Opsaridium peringueyi*) and various semi-rheophilic species (*Labeobarbus marequensis, Labeobarbus polylepis, Varicorhinus nelspruitensis* etc.). Max. depth (0.47 m) will also be more than adequate to allow free movement (migration) even for larger species (such as *Varicorhinus nelspruitensis*, *Labeobarbus marequensis*). The minimum discharge recommended to maintain the PES during wet droughts period is 0.7 m^3/s. Adequate fast habitats (FD, FI and FS), max. depth (>0.3 m) and water quality will still be maintained to provide sufficient habitats for rheophilic and semi-rheophilic species during droughts. **INVERTS:** At this discharge, there will be 51% FS/FI to FD habitat available, which is very favourable to the sensitive macroinvertebrate assemblages. The following indicators for fast flows were assessed for AS1: Cobble dwellers with a preference for fast flows, Perlidae and Hydropsychidae (>0.6 m/s); and highly sensitive Heptageniidae in moderate flows (0.3 – 0.6 m/s). These flows will be adequate to allow for these sensitive taxa to thrive at a stress level of 6.8. The sensitive Atyidae is a vegetation dweller and an indicator for inundated marginal vegetation habitats. The flow in the system will create ample habitat for this taxon.		
Feb	60^{th}	1.580	**FISH:** Stress of 5. More than adequate fast habitats (FD: 19%, FI: 21% and FS: 20%) will be available to provide habitat (feeding and breeding) and water quality for rheophilic species (*Amphilius uranoscopus*, *Chiloglanis anoterus*, *Chiloglanis emarginatus*, *Chiloglanis swierstrai*, *Enteromiusargenteus*, *Opsaridium peringueyi*) and various semi-rheophilic species (BMAR, BPOL, VNEL etc.). Maximum depth (0.49m) will also be more than adequate to allow free movement (migration) even for larger species (such as *Varicorhinus nelspruitensis*, *Labeobarbus marequensis*). The minimum discharge recommended to maintain the PES during wet droughts period is 1.1 m^3/s. Adequate fast habitats (FD: 12%, FI: 21% and FS: 17%), max. depth (>0.3 m) and water quality will still be maintained to provide sufficient habitats for rheophilic and semi-rheophilic species. **INVERTS:** At this discharge, there will be 60% FS/FI to FD habitat available, which is very favourable to the sensitive macroinvertebrate assemblages. The following indicators for fast flows were assessed for AS1: Cobble dwellers with a preference for fast flows, Perlidae and Hydropsychidae (>0.6 m/s); and highly sensitive Heptageniidae in moderate flows (0.3 – 0.6 m/s). These flows will be adequate to allow for these sensitive taxa to thrive at a stress level of 5.0. The sensitive Atyidae is a vegetation dweller and an indicator for inundated marginal vegetation habitats. The flow in the system will create ample habitat for this taxon.	1.100	1.100

10.5 HIGH FLOW EWR

The high flow EWR as output from the RDRM model was provided to specialists for review (**Table 10.4**).

Table 10.4 Desktop EWR high flow recommendations

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	17.715	72	4	1.938
2	Annual	38.234	80	3	4.647
3	Annual	61.756	88	1	8.256
4	1:2 year	90.759	96	1	13.237
5	1:5 year	178.607	112	1	30.391

Adjustments to the high flow EWR are indicated and motivated in **Table 10.5.**

Table 10.5 Desktop EWR high flow recommendations

Class	Frequency	Peak (m^3/s)	Vegetation Motivation	Geomorphology Motivation
1	Annual	12 - 14	Required to activate and inundate a proportion of marginal and lower zone graminoids (*Persicaria lapathifolia, Cyperus marginatus, Phragmites australis, Ischaemum fasciculatum*). The desktop estimation of 17.7 m^3/s is acceptable for riparian vegetation.	Overtops marginal zone bench on LB, will promote deposition of sand bedload if present; sand and very fine gravel can be entrained from the channel bed, limited entrainment of small gravel.
2	Annual	34	Required to inundate marginal zone riparian trees (*Salix mucronata*) and lower zone graminoids (*Miscanthus junceus*). The desktop estimation of 38.2 m^3/s is acceptable for riparian vegetation since this achieves the same function.	This flow will activate the secondary channel on the RB but will not cause to to overflow across the high flood bench; very fine gravel to small gravel can be entrained from the channel bed, limited entrainment of small to medium gravel.
3	Annual	47 - 60	Required to activate and inundate upper zone (flood feature) riparian trees (*Combretum erythrophyllum*). The desktop estimation of 61.7 will perform this function and is acceptable for an annual flood for riparian vegetation.	Not specified for geomorphology, no adequate indicators.
4	1:2 year		Not specified for vegetation, no adequate indicators.	Not specified for geomorphology, no adequate indicators.

Class	Frequency	Peak (m^3/s)	Vegetation Motivation	Geomorphology Motivation
5	1:5 year	100+	Required to activate terrestrial and alien woody species (such as *Acacia mearnsii*) to prevent terrestrialisation of the riparian zone and encroachment of alien invasive species into the lower sub-zones. The desktop estimation of 178.6 m^3/s will achieve this function and is acceptable for riparian vegetation.	This flow overtops the high bench on the RB and will activate flow out of the secondary channel. Small gravel can be entrained from the channel bed, limited entrainment of medium gravel. Widespread evidence of flooding up to this level.

10.6 EWR AS1 RECOMMENDATIONS FOR A C ECOLOGICAL CATEGORY

The flow requirements are summarised in **Table 9.6** to **9.8**. **The low flow EWR** is 40.06 MCM and equates to 12.2% of the nMAR. The **Total flow EWR** is 70.850 MCM which equates to 21.6% of the nMAR. The text in red on the flow duration tables refers to the wettest (February) and driest (September) months.

Table 10.6 Final high flow requirements

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	12.226	68	4	1.263
2	Annual	34.201	80	3	4.157
3	Annual	47.269	84	1	6.032
4	1:2 year	75.305	92	1	10.526
5	1:5 year	0:230	96	1	14.587

Table 10.7 Low flow assurance rules (m^3/s)

m^3/s	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.81	1.60	0.92	0.57	0.42	0.35	0.31	0.27	0.23	0.20
Nov	3.58	2.22	1.40	0.84	0.58	0.48	0.41	0.36	0.32	0.24
Dec	3.58	3.31	1.82	1.31	0.92	0.69	0.62	0.54	0.45	0.30
Jan	4.16	2.70	2.30	1.59	1.25	1.04	0.92	0.76	0.61	0.51
Feb[1]	2.92	2.34	1.91	1.54	1.29	1.10	0.95	0.82	0.69	0.61
Mar	3.40	2.98	1.86	1.44	1.23	1.08	0.92	0.79	0.69	0.57
Apr	3.62	2.42	1.74	1.29	1.08	0.96	0.89	0.80	0.67	0.59
May	3.39	2.27	1.54	1.05	0.82	0.74	0.67	0.57	0.53	0.49
Jun	2.92	1.96	1.21	0.79	0.60	0.52	0.45	0.40	0.38	0.38
Jul	2.30	1.66	1.00	0.64	0.45	0.39	0.34	0.31	0.29	0.28
Aug	1.95	1.40	0.83	0.52	0.38	0.34	0.29	0.26	0.24	0.24
Sep[1]	1.99	1.24	0.76	0.48	0.36	0.30	0.26	0.23	0.20	0.18

[1] The low flows for the 60th and 90th percentiles for the wettest (February) and driest (September) month.

Table 10.8 Total assurance rules (MCM)

MCM	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	10.506	5.555	3.721	1.526	1.116	0.938	0.822	0.711	0.605	0.546
Nov	23.873	10.156	7.797	6.344	3.869	2.497	2.337	0.943	0.828	0.632
Dec	27.461	18.949	10.908	8.92	6.624	6.014	5.253	2.72	2.434	0.811
Jan	28.256	21.292	14.582	10.28	7.515	6.933	6.614	4.55	2.91	1.379
Feb	22.981	14.28	10.684	7.916	7.295	6.674	3.761	3.258	1.696	1.49
Mar	18.419	14.02	9.139	8.021	4.546	4.168	2.462	2.119	1.838	1.536
Apr	13.539	10.423	5.77	4.618	2.807	2.489	2.315	2.063	1.744	1.518
May	10.351	6.068	4.12	2.802	2.194	1.993	1.785	1.534	1.417	1.315
Jun	7.559	5.071	3.125	2.042	1.544	1.343	1.172	1.043	0.982	0.98
Jul	6.152	4.437	2.689	1.706	1.199	1.054	0.92	0.84	0.78	0.758
Aug	5.234	3.759	2.217	1.381	1.018	0.905	0.773	0.696	0.642	0.631
Sep	5.148	3.222	1.978	1.233	0.924	0.782	0.685	0.606	0.524	0.464

11 EWR NG1: NGWEMPISI RIVER

11.1 PRESENT ECOLOGICAL STATE

The PES for each component as well as for the EcoStatus are summarised in **Table 11.1** below.

Table 11.1 Present Ecological State results and comments

Component	PES	Comment
Instream IHI[1]	**C (64.3%)**	Flow changes due to upstream Morgenstond and Westoe dams. Non-flow related impacts due to sedimentation and marginal and non-marginal bank modification as well as connectivity issues. **Confidence: 3.5**
Riparian IHI	**C/D (61.8%)**	Flow changes due to upstream dams and non-flow related impacts due to invasive alien vegetation. **Confidence: 3**
Water quality	**B (85.5%)**	Main water quality impactors are extensive forestry, roads and erosion along the river. **Confidence: 3.5**. Diatoms indicate Good water quality.
Geomorphology	**B (83.3%)**	Upstream dams (Morgenstond and Jerico) plus weir immediately above site trap some sediment and reduce frequency and magnitude of floods; small increase is sediment supply from cultivated lands and forestry but slopes mostly gentle to moderate. Bedrock influence increases resilience to change. Instream and marginal riparian habitat appear to be in good condition. **Confidence: 3.23**
Riparian vegetation	**B/C (77.4%)**	The marginal zone was well vegetated with tufted grasses and reeds and overhanging vegetation and in-channel growth. Some woody vegetation was also prevalent and common, the shrub *Cliffortia* mainly (with overhang) but also *Salix mucronata.* The RB of the non-marginal zone was dominated by woody vegetation while the LB was dominated by non-woody vegetation (burnt grass mainly). Aliens included *Sesbanea*, Wattle and *Solanum mauritianum.* **Confidence: 2.0.**
Fish	**C (72.8%)**	Based on available information it is estimated that 14 fish species are expected in this reach under reference conditions (2022 update). Five indigenous and one alien fish species were sampled at the site during IUCMA monitoring during 2019. In general, the FROC of the recorded species was low and could have been altered as a result of flow regulation and loss of instream habitat due to sedimentation (IUCMA, 2019). Eight indigenous fish species were sampled during the 2022 survey. It is estimated that all fish species may still be present under current conditions at reduced abundance and FROC. The FRAI was amended for the purpose of the 2022 study with a score of 72.8% (Category C) calculated. The primary impacts responsible for the current state of the fish assemblage include altered water quality (nutrients, salinity, toxics), slight bed modification (sedimentation), altered flows. **Confidence: 4**
Macro-invertebrates	**B (87.3%)**	The presence of six taxa with a preference for fast flowing water and a preference for loose cobbles indicate a “Largely natural with few modifications” condition at this site. Two taxa with a preference for abundant vegetation and five taxa with a moderate requirement for unmodified physico-chemical conditions are also present, which added to the favourable MIRAI score. **Confidence: 4**
Instream	**B/C (80.36%)**	The Instream PES was derived using the EcoStatus model.
EcoStatus	**B/C (79.8%)**	The EcoStatus EC was derived using the EcoStatus model.

Table 11.2 Present Ecological State: Key flow and non-flow related impacts

Component	Causes	Sources	Flow or non-flow related
Water quality	Elevated turbidity and small toxics input expected. Although urban impacts from upstream Amterdam may be expected, water quality data indicates a Good (B category) state for the site.	Upstream forestry and roads network are the primary contributors to water quality state. Some elevation in nutrients linked to upstream urban impacts and cultivation, evident.	Non-flow
Geomorphology	Reduction is bedload sediment (sands and gravels); reduced floods.	Upstream dams and weir.	Flow
Riparian vegetation	Altered species composition.	Alien plant species (perennial and invasive, including *Sesbanea, Solanum mauritianum*).	Non-flow
Fish	Altered water quality, bed modification, reduced habitat suitability and abundance.	Amsterdam, agriculture, livestock farming, WWTW, informal settlement, catchment erosion, agriculture, dams and weirs, water abstraction.	Flow and non-flow
Macroinvertebrates	Sensitive taxa impacted by deteriorating water quality parameters (increased nutrients), as well as siltation.	Trampling and grazing result in localised erosion.	Non-flow

In summary, the B/C EcoStatus represents the response of the biota to largely non-flow related causes and sources such as upstream agricultural activities, towns/settlements, WWTW, forestry and alien species. Flow related impacts are associated with reduced floods and in general flow modification from two upstream dams.

11.2 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The EIS evaluation resulted in a MODERATE importance. The highest scoring metrics were:

- Rare and endangered fish species.
- Riparian / wetland unique biota.
- Riparian / wetland species/taxon richness.
- Migration corridor for instream and riparian biota.

11.3 RECOMMENDED ECOLOGICAL CATEGORY (REC)

Due to the moderate importance, the REC is set to maintain the PES of a **B/C EC**.

11.4 LOW FLOW ECOLOGICAL WATER REQUIREMENTS

The low flow requirements as an initial estimate from the RDRM model was provided to specialists for a review and are summarised in **Table 11.3**.

Table 11.3 Low flow EWR review and recommendations: B/C PES

Month	Percentile	RDRM Discharge m^3/s	Review	Recommended discharge (m^3/s)	Final discharge (m^3/s)
Sep	90th	0.086	**FISH:** RDRM discharge result in high stress of 7.8. Very limited fast habitat available (no FD and FI, FS: 3%, FVS: 4%), max depth of 0.23 m. Very limited fast habitat available for indicator spp. (*Amphilius uranoscopus*, *Chiloglanis anoterus*, *Labeobarbus marequensis*). Flows cannot be reduced further as it will result in loss of rheophilic species. Ideally flow should be no lower than 0.1 m^3/s, where some FI will at least become available. **INVERTS:** At this discharge there will only be 3% FS habitat available, as well as 4% FVS which does not add significant habitat for macroinvertebrates at the site. The following indicators taxa were assessed for fast flows at NG1 are: Cobble dwellers with a preference for fast flows, Perlidae, Philopotamidae, Psephenidae and Hydropsychidae (>0.6 m/s); and highly sensitive Heptageniidae in moderate flows (0.3 – 0.6 m/s). Flows at a discharge of 0.086 m^3/s will create very little habitat to allow for the expected sensitive taxa to survive a stress level of 7.8. Water levels of max. 0.23 m will inundate adequate portions of the marginal vegetation habitats, exerting a high level of stress on the Coenagrionidae (indicator vegetation). The 0.086 m^3/s discharge is thus not adequate to maintain the B/C EcoStatus. A recommended discharge of 0.1 m^3/s is thus supported.	0.100	0.090
Sep	60th	0.185	**FISH:** RDRM discharge result in high stress of 6.8. Very limited fast habitats available (no FD, FI: 2%, FS: 5%), max. depth of 0.29 m. These flows may be limiting to most indicator spp (*Amphilius uranoscopus*, *Chiloglanis anoterus*, *Labeobarbus marequensis*) during dry season. Lowest recommended discharge to maintain PES is 0.25 m^3/s (stress of 5.7). These flowS will ensure adequate fast habitat, depth and water quality to maintain flow sensitive indicator spp. **INVERTS:** At this discharge there will be 7% FS/FI depth habitat available, with no FD flows. The 4% FVS does not add significant habitat for macroinvertebrates at the site. The following indicators taxa were assessed for fast flows at NG1 are: Cobble dwellers with a preference for fast flows, Perlidae, Philopotamidae, Psephenidae and Hydropsychidae (>0.6 m/s); and highly sensitive Heptageniidae in moderate flows (0.3 – 0.6 m/s). Flows at a discharge of 0.185 m^3/s will create very little additional habitat to allow for the expected sensitive taxa to survive a stress level of 6.8 to improve habitat for dispersion and reproduction. The Coenagrionidae (indicators for vegetation biotopes) will be able to survive in the limited inundated habitat. The 0.185 m^3/s discharge is thus not adequate to maintain the B/C EcoStatus. A recommended discharge of 0.25 m^3/s is thus supported.	0.250	0.190
Feb	90th	0.824	**FISH:** RDRM discharge result in moderate stress of 4.8. Abundant fast habitats available (FD: 8%, FI: 9%, FS: 6%), max. depth of 0.46 m. More than adequate to sustain all life-stages of indicator spp. (*Amphilius uranoscopus*, *Chiloglanis anoterus*, *Labeobarbus marequensis*) during wet season (droughts). Lowest recommended discharge to maintain PES is	0.600	0.600

Month	Percentile	RDRM Discharge m^3/s	Review	Recommended discharge (m^3/s)	Final discharge (m^3/s)
			0.6 m^3/s (stress of 5.4). Adequate fast habitats (FD: 5%, FI: 8%, FS: 6%), max. depth (0.42 m) and water quality will be maintained to support flow sensitive indicator spp. **INVERTS:** At a discharge of 0.824 m^3/s there will be 15% FS/FI depth habitat available, as well as 8% FD. The taxa requiring faster flows will have adequate habitat created by the favourable flow levels. These assemblages include the indicator taxa preferring fast flows: Perlidae, Philopotamidae, Psephenidae and Hydropsychidae (>0.6 m/s); and highly sensitive Heptageniidae in more moderate flows (0.3 – 0.6 m/s). SS aquatic biotopes (53% of all biotopes) will inundate portions of the marginal vegetation habitats. The Coenagrionidae (indicators for vegetation biotopes) will thrive in the abundant inundated habitat at a stress level of 4.8. Reduced flows recommended for fish will be adequate to maintain invertebrate PES.		
Feb	60^{th}	1.359	**FISH:** RDRM discharge result in low stress of 3.8. Abundant fast habitats available (FD: 20%, FI: 7%, FS: 8%), max. depth of 0.54 m. More than adequate to sustain all life-stage processes of indicator spp. (*Amphilius uranoscopus*, *Chiloglanis anoterus*, *Labeobarbus marequensis*) during wet season. Lowest recommended discharge to maintain PES is 0.85 m^3/s (stress of 4.4). Adequate fast habitats (FD: 14%, FI: 8%, FS: 7%), max. depth (0.5 m) and water quality will be maintained to support flow sensitive indicator spp. **INVERTS:** At a discharge of 1.359 m^3/s there will be 15% FS/FI depth habitat available, as well as 20% FD. The taxa requiring faster flows will have adequate habitat created by the favourable flow levels. These assemblages include the indicator taxa preferring fast flows: Perlidae, Philopotamidae, Psephenidae and Hydropsychidae (>0.6 m/s); and highly sensitive Heptageniidae in more moderate flows (0.3 – 0.6 m/s). SS aquatic biotopes (51% of all biotopes) will inundate most of the marginal vegetation habitats. The Coenagrionidae (indicators for vegetation biotopes) will thrive in the abundant inundated habitat at a stress level of 3.8. Reduced flows recommended for fish will be adequate to maintain invertebrate PES.	1.000	1.000

11.5 HIGH FLOW EWR

The high flow EWR as output from the RDRM model was provided to specialists for review (**Table 11.4**).

Table 11.4 Desktop EWR high flow recommendations

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	18.314	57	4	1.564
2	Annual	39.479	61	3	3.611
3	Annual	74.992	65	1	7.315
4	1:2 year	136.918	72	1	14.977
5	1:5 year	354.150	88	1	47.348

Adjustments to the high flow EWR are indicated and motivated in **Table 11.5.**

Table 11.5 Desktop EWR high flow recommendations

Class	Frequency	Peak (m^3/s)	Vegetation Motivation	Geomorphology Motivation
1	Annual	5	Required to activate and inundate a proportion of marginal and lower zone graminoids (*Persicaria lapathifolia, Cyperus marginatus, Phragmites australis, Ischaemum fasciculatum*). The desktop estimation of 17.7 m^3/s is acceptable for riparian vegetation.	Overtops marginal zone bench on LB, will promote deposition of sand bedload if present; sand and very fine gravel can be entrained from the channel bed, limited entrainment of small gravel.
2	Annual	20	Required to inundate marginal zone riparian trees (*Salix mucronata*) and lower zone graminoids (*Miscanthus junceus*). The desktop estimation of 38.2 m^3/s is acceptable for riparian vegetation since this achieves the same function.	This flow will activate the secondary channel on the RB but will not cause to overflow across the high flood bench; very fine gravel to small gravel can be entrained from the channel bed, limited entrainment of small to medium gravel.
3	Annual	40	Required to activate and inundate upper zone (flood feature) riparian trees (*Combretum erythrophyllum*). The desktop estimation of 61.7 m^3/s will perform this function and is acceptable for an annual flood for riparian vegetation.	Not specified for geomorphology, no adequate indicators.
4	1:2 year	80	Not specified for vegetation, no adequate indicators.	Not specified for geomorphology, no adequate indicators.
5	1:5 year	100+	Required to activate terrestrial and alien woody species (such as *Acacia mearnsii*) to prevent terrestrialisation of the riparian zone and encroachment of alien invasive species into the lower sub-zones. The desktop estimation of 178.6 m^3/s will achieve this function and is acceptable for riparian vegetation.	This flow overtops the high bench on the RB and will activate flow out of the secondary channel. Small gravel can be entrained from the channel bed, limited entrainment of medium gravel. Widespread evidence of flooding up to this level.

11.6 EWR NG1 RECOMMENDATIONS FOR A B/C ECOLOGICAL CATEGORY

The flow requirements are summarised in **Table 9.6** to **9.8**. **The low flow EWR** is 30.46 MCM and equates to 19.5% of the nMAR. The **Total flow EWR** is 50.82 MCM which equates to 32.5% of the nMAR. The text in red on the flow duration tables refers to the wettest (February) and driest (September) months.

Table 11.6 Final high flow requirements

Flood Class	Frequency	Peak (m^3/s)	Duration (hours)	Number of Events	Volume (MCM)
1	Annual	5.172	53	4	0.410
2	Annual	20.122	61	3	1.840
3	Annual	40.757	65	1	3.975
4	1:2 year	80.639	76	1	9.311
5	1:5 year	162.551	88	1	21.732

Table 11.7 Total assurance rules (MCM)

m^3/s	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.27	1.06	0.65	0.52	0.37	0.28	0.22	0.17	0.12	0.09
Nov	2.10	1.59	1.27	0.85	0.60	0.43	0.30	0.23	0.19	0.14
Dec	2.81	2.45	1.84	1.32	0.97	0.71	0.55	0.38	0.29	0.21
Jan	3.49	2.89	2.47	1.56	1.19	0.97	0.80	0.64	0.51	0.50
Feb[1]	3.49	2.97	2.37	1.78	1.30	1.00	0.82	0.69	0.60	0.43
Mar	3.42	2.89	2.44	1.75	1.26	0.98	0.75	0.65	0.49	0.38
Apr	3.01	2.61	2.13	1.55	1.14	0.87	0.73	0.59	0.43	0.19
May	2.40	1.21	0.96	0.82	0.66	0.56	0.43	0.35	0.21	0.10
Jun	1.12	0.72	0.57	0.46	0.39	0.34	0.29	0.23	0.16	0.11
Jul	0.64	0.49	0.35	0.30	0.25	0.21	0.18	0.15	0.12	0.08
Aug	0.49	0.33	0.28	0.25	0.20	0.17	0.14	0.12	0.10	0.07
Sep[1]	0.50	0.37	0.30	0.24	0.22	0.19	0.15	0.13	0.09	0.06

[1] The low flows for the 60th and 90th percentiles for the wettest (February) and driest (September) month.

Table 11.8 Total assurance rules (MCM)

MCM	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	5.245	3.208	1.738	1.524	1.09	0.742	0.579	0.444	0.321	0.228
Nov	10.718	6.047	5.128	4.044	2.379	1.527	1.192	0.606	0.485	0.351
Dec	23.177	12.227	8.893	5.789	4.438	3.743	3.218	1.438	1.181	0.569
Jan	31.087	16.305	11.82	8.16	5.445	4.444	3.996	3.305	1.784	1.327
Feb	22.288	12.465	9.413	6.589	5.015	4.288	3.838	2.104	1.885	1.06
Mar	13.944	11.411	8.365	6.532	5.21	3.274	2.43	1.729	1.324	1.023
Apr	9.646	6.884	5.922	4.44	3.29	2.558	1.882	1.531	1.104	0.498
May	6.674	3.248	2.568	2.196	1.77	1.508	1.152	0.94	0.552	0.265
Jun	2.914	1.856	1.478	1.184	1	0.876	0.744	0.608	0.418	0.284
Jul	1.716	1.314	0.948	0.804	0.68	0.55	0.482	0.4	0.332	0.227
Aug	1.304	0.88	0.748	0.678	0.53	0.45	0.382	0.33	0.27	0.189
Sep	1.294	0.962	0.768	0.634	0.58	0.48	0.4	0.348	0.224	0.159

12 PROVISIONAL ESTUARY ECOCLASSIFICATION

12.1 ESTUARY METHODS

Similar to rivers and wetlands, the health (also called the PES) of an estuary is typically defined on the basis of current condition (i.e., the extent to which it differs from its reference or natural condition). Based on the above, estuary condition is described using the six Ecological Categories (EC), ranging from natural (A) to critically modified (F) (**Table 12.1**). The fact that the physical conditions in estuarine systems are more dynamic than those of other aquatic ecosystems means that severe degradation of an estuary may involve a shift from a dynamic to a more stable, or unidirectional, system. This means that the loss of dynamic function *per se* is an important indication of declining estuarine health (DWAF 2008b; Van Niekerk *et al*., 2013). Thus, in an estuarine health assessment, measures of these different states need to be sufficiently robust so that different practitioners/disciplines will arrive at the same categorisation. Note the different scoring ranges from rivers.

Table 12.1 Schematic illustration of the relationship between loss of ecosystem condition and functionality (Van Niekerk *et al*., 2019)

Condition (% of pristine)	≥91%	90-75	75 - 61	60 - 41	40-21	≤20
Continuum	A A/B	B B/C	C C/D	D D/E	E E/F	F
Ecological Management Category (DWS)	A Natural	B Largely natural / few changes	C Moderately modified	D Largely modified	E Highly degraded	F Extremely degraded
NBA Ecological modification	Natural/Near natural		Moderate	Heavily	Severe/Critical	
Functionality	Retain Process & Pattern (Representation)		Some loss of Process & Pattern	Significant loss of Process & Pattern	Little Process & Pattern	
Restoration cost	None/ Low		Low/ Medium	High	Very high, potentially irreversible structural changes	

An assessment is undertaken by a multidisciplinary group of estuarine scientists in a workshop setting, based on their collective understanding of the likely impacts affecting each system. Expert knowledge and available information were all used to build a “picture” of the probable pristine state of each estuary and the changes under current conditions. The Estuarine Health Index (EHI) is applied to all levels of ecological water requirement studies (comprehensive, intermediate or rapid), with only the level of information supporting the study and level of confidence varying. For each variable, the conditions are estimated as a percentage (0 – 100%) of the pristine health. Scores are then weighted and aggregated so that the final score reflects the present health of the estuary as a percentage of the pristine state (**Table 12.1**). Both abiotic and biotic variables are included as the relationships between the abiotic and biotic variables are often not well understood and because the biotic response to certain abiotic variables can be lagging.

The individual health scores were aggregated as illustrated in **Figure 12.1**. In estuaries, unlike the terrestrial environment, degradation or loss of habitat seldom means a complete loss of system health or function. This can only happen if an estuary becomes completely degraded, e.g. changed into a parking lot or golf course. In most cases, degradation means loss of processes or loss of biological functionality, e.g. the estuarine space is filled with a different salinity condition or different

species composition. This loss of functionality happens on a continuum, with estuaries which retain more than 90% of their natural processes and pattern being rated as Natural and estuaries degraded to less than 40% of natural functionality rated as severely degraded.

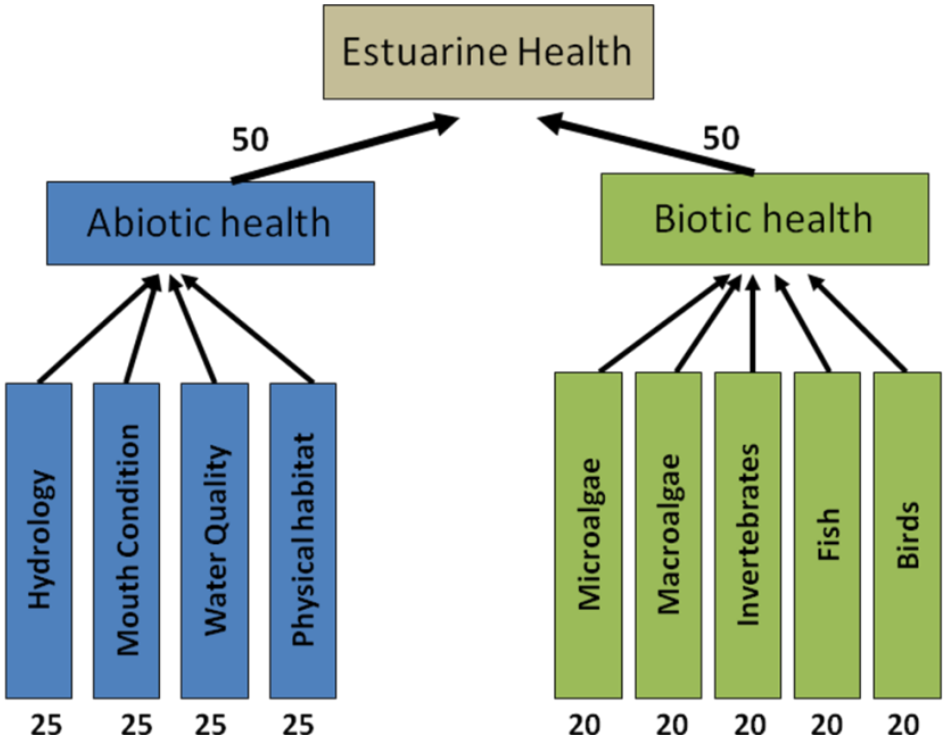


Figure 12.1 Components and weightings of the EHI (DWAF, 2008b)

The REC represents the level of protection assigned to an estuary. The first step is to determine the 'minimum' assigned category, based on PES. The relationship between EHI score, PES and REC is given in **Table 12.2**.

Table 12.2 Relationship between the EHI, PES and REC

EHI score	PES	Description	REC
91 – 100	A	Unmodified, natural	A
76 – 90	B	Largely natural with few modifications	B
61 – 75	C	Moderately modified	C
41 – 60	D	Largely modified	D
21 – 40	E	Highly degraded	-
0 – 20	F	Extremely degraded	-

Thus the PES defines the minimum EC or REC. The degree to which the REC needs to be elevated above the PES depends on the level of **importance** and level of **protection or desired** protection of a particular estuary (**Table 12.3**).

Table 12.3 Estuary protection status and importance, and the basis for assigning a REC (DWA, 2008b)

Protection status and importance	REC	Policy basis
Protected area	A or BAS*	Protected and desired protected areas should be restored to and maintained in the best possible state of health
Desired Protected Area		
Highly important	PES + 1, min B	Highly important estuaries should be in an A or B category
Important	PES + 1, min C	Important estuaries should be in an A, B or C category
Of low to average importance	PES, min D	Estuaries to remain in a D category

* BAS = Best Attainable State.

12.2 PRESENT ECOLOGICAL STATE

Nine estuaries occur in the study areas, with the uMhlathuze estuarine lake system subdivided to create an estuarine bay (Richards Bay) and a predominantly open system (uMhlathuze Sanctuary) to accommodate a port development in the 1970s. Most of the estuaries in the study area are in a degraded state (D to E Category), due to high to very high pollution, habitat loss and fishing pressure (**Table 12.4**). Previous assessments did not consider most of the estuaries in the study area to be under high flow modification pressure, other than iSiyaya and Richards Bay. Only four estuaries are estimated to remain in a near-natural state (A/B to B Category), namely aMatigulu/iNyoni, uMlalazi, uMgobezeleni and Kosi.

However, a recent field visit (October 2022) to six of the estuaries in the study area highlighted further decline in conditions in four systems:

- aMatigulu/iNyoni – land-use change (housing), possible increase in water quality pressures (including large-scale use of Dokodweni beach node in lower reaches) , illegal gill netting.
- iSiyaya – flow and water quality (sediment pollution) pressures and illegal gillnetting.
- iNhlabane – flow pressure (no freshwater inflow due to Nhlabane barrage/dam), illegal gillnetting.
- Kosi – land-use change, increase in mangrove harvesting, an escalation in the exploitation of living resources (increase in fish traps and illegal gill netting), possible increase in water quality pressures.

Note that ecological categories refer to the PES as defined by the National Biodiversity Assessment of 2018. These will be refined and updated during the study, with final categories determined during the Estuary Specialist Workshop in February 2023.

Table 12.4 A summary of the NBA PES (2018) and relevant field observation pertaining to the PES (Van Niekerk *et al*., 2019)

Secondary Catchment	Estuary	PES (NBA 2018)	Field observations (October 2022)
W11	aMatigulu/ iNyoni	B	System was closed with overwash from the sea at low water levels. Estuary in a relative good condition, but possible decline in condition. Housing developments expanding in lower reaches (iNgonyama Trust land), evidence of increased nutrification (lower 3/4 km of sediment surface covered with filamentous algae (vegetation team to identify species). Observed significant areas of submerged macrophyte and filamentous algae. Pending water quality result, but blooms can be developing when water level is low after a mouth breaching event. Previous studies recorded a total of 54 species in the estuary as opposed to 15 in our 1-day visit. Benthic inverts in very high numbers of *Terebia granifera*. High numbers of Palearctic waders, including Bar-tailed Godwit. Large numbers of White-fronted Plovers and Sanderlings reflecting sandy nature of substrate. Large numbers of waterfowl (ducks and geese) in upper reaches, reflecting large expanses of submergent vegetation highly favoured as a food source.
W13	iSiyaya	E	Mouth Closed. Declining further in condition. Very little flow reaching the estuary. Only small stagnant pools observed in mouth area. Very high turbidity observed in middle and upper reaches linked to possible upstream slimes dam input and contamination. To be confirmed with satellite imagery. This said, a total of 18 species of fish were sampled in the lower reaches which compares well with the 13 recorded in previous studies. The relatively low species count in this, and earlier studies is typical of a predominantly closed estuary. Very few waterbirds present. The high turbidity due to mine siltation highly negative for visual piscivorous waterbird species and also likely highly negative for invertebrate feeders if the substrate is smothered by this silt.
W13	uMlalazi	B	Field observations: Mouth open. In a good condition, but some concerns over water quality. Several oxygen-deprived zones noted (particularly in mid-lower reaches) in the bottom water column layer (<3% saturation). Upper reaches show increasing livestock influences (cattle/goats) and possible informal sand mining. Healthy mangroves and salt marsh habitat. Some macroalgal growth in the middle reaches. Very high species diversity, with for example 46 fish species recorded. Very important nursery area in the region. High numbers of Palearctic waders, especially Common Sandpiper – reflecting the muddy substrate.
W12	uMhlathuze	D	Transnet industrial action and civil unrest prevented access to uMhlathuze Sanctuary. Will use available information from the Department of Fisheries, Forestry and Environment (DFFE) uMhlathuze/Richards Bay Estuarine Management Plan.
W12	Richards Bay	D/E	Use information from uMhlathuze/Richards Bay Estuarine Management Plan.
W12	iNhlabane	E	Field observations: Mouth Closed. Significant further decline in condition. Very high unnatural sand dune has formed in mouth indicating years of flow depravation. No connection to the sea. Mouth has not been open in years. EWR cannot have been released in years. System was completely fresh as indicated by leeches, water lilies and tadpoles. Extensive loss of open water area due to macrophyte growth. Water body infested with bilharzia snail vectors. No flow over the weir. Fishway non-functional. No estuarine functionality remains in what was once an important estuarine lake in the region due to freshwater flow depravation. Only three species of fish were sampled, all freshwater taxa tolerant of poor water quality. Extensive infestation by alien invasive *Terebia granifera* snails. Other macroinvertebrates sampled seemed only to be various dragonfly larvae supporting no current estuarine function. System is now used for livestock watering (evidence around lower estuary margins), further degrading water quality and nutrients allowing the proliferation of macrophytes which have closed off the middle reaches (see satellite imagery).
W2	iMfolozi/ uMsunduze	D	No new worked planned. Informed by Lake St Lucia Volume 1 &2 Intermediate EcoClassification and EWR Assessment Report (DWS, 2016).
W3	St Lucia	D/E	No new worked planned. Informed by Lake St Lucia Volume 1 &2 Intermediate EcoClassification and EWR Assessment Report (DWS, 2016).

Secondary Catchment	Estuary	PES (NBA 2018)	Field observations (October 2022)
W7	uMgobezeleni	**B**	Mouth open. Limited salinity penetration in lower reaches. System in good condition. Fully functional estuarine lake system. More important than previously indicated. New recruits of fish were recorded in uMgobezeleni Lake (< 2 weeks old freshwater mullet that recruited from the sea). New individuals of black mangroves observed. However, urgent action needed to protect mangroves (e.g., road through mangroves) and fish (illegal gillnets in lake). A total of 18 fish species were sampled which compares well with 14 recorded across all previous studies. Of interest, is the existence of spotted bass *Micropterus punctulatus*, probably descendants of bass introduced in the 1950s to 1970's.
W7	Kosi	**A/B**	Mouth open. Lake water levels higher than in 2016. System shows signs of drought recovery. Despite being a very Important Estuarine Lake in a formally protected area there are significant signs of further decline in condition – system now likely to be B Category. Significant increase in clearing of natural vegetation (land use change), increase harvesting pressure on mangroves, more fish traps (first time fish traps observed in 3de Lake), and gill nets observed for the first time in 4th Lake. Significant submerged macrophyte and macroalgal growth were observed in 3rd lake. Local fisherman indicated that this has not happened before in living history, e.g., macroalgal growth in fish traps. Indicating nutrient enrichment but will need to confirm source. In all, 25 species of fish were caught and at least another 10 were seen whilst sampling and using mask and snorkel.

12.3 ECOLOGICAL AND CONSERVATION IMPORTANCE

12.3.1 Importance rating

The Estuary Importance Score (EIS) for an estuary takes size, habitat diversity, the rarity of the estuary type within its biographical zone, biodiversity importance of the estuary into account (**Table 12.6**) (DWA, 2008b). Biodiversity importance, in turn, is based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices. These importance scores ideally refer to the system in its natural condition. The scores have been determined for all South African estuaries, apart from functional importance, which is scored by the specialists during EWR workshops (planned for February 2023) (Turpie 2002; Turpie and Clark 2007; DWA, 2008b). **Table 12.5** summarises the relationship between EIS and their significance (DWA, 2008b).

Table 12.5 Estuarine importance scores (EIS) and significance

Importance score	Comment
81 – 100	Highly important
61 – 80	Important
60 – 0	Low to average importance Important

Five of the estuaries in the study area are of High ecological importance, namely uMlalazi, uMhlathuze, iMfolozi/uMsunduze St Lucia, and Kosi (**Table 12.6**). These systems represent some of South Africa's most important estuarine estuaries. In addition, three systems are also of Importance, aMatigulu/iNyoni, Richards Bay, and iNhlabane. Only two systems in the study area were evaluated of relative average importance, namely iSiyaya and uMgobezeleni, due to their smaller sizes. The recent field visit disputes the low importance ranking of uMgobezeleni given that it is a fully functional estuarine lake system, one of few that is still in good condition in the country.

Table 12.6 A summary of estuary importance

Secondary Catchment	Estuary	Size	Habitat Diversity	Zonal type rarity	Biodiversity Importance	Estuary Importance	Biodiversity Importance Rating
W11	aMatigulu/ iNyoni	90	70	30	89	79	Important
W13	iSiyaya	30	60	10	47	40	Low to Average Importance
W13	uMlalazi	90	90	30	95.5	85	High Importance
W12	uMhlathuze	100	100	80	53.5	86	High Importance
W12	Richards Bay	100	0	80	85	69	Important
W12	iNhlabane	50	50	70	86	61	Important
W2	iMfolozi/ uMsunduze	90	100	70	93.5	91	High Importance
W3	St Lucia	100	100	70	98.5	97	High Importance
W7	uMgobezeleni	10	80	70	37	40	Low to Average Importance
W7	Kosi	100	100	70	100	97	High Importance

12.3.2 Conservation Importance

The National Biodiversity Assessment 2011 (NBA 2011) (Van Niekerk and Turpie, 2012; Turpie *et al*., 2012) developed a biodiversity plan for the estuaries of South Africa by prioritising and establishing which of them should be assigned partial or full Estuarine Protected Area (EPA) status. This biodiversity plan followed a systematic approach that took pattern, process and biodiversity persistence into account. While the plan has not explicitly taken social and economic costs and benefits into consideration, it used ecosystem health as a surrogate for the former as estuaries where the opportunity costs of protection are likely to be high are also likely to be heavily-utilised systems that are in a lower state of health.

The plan indicates that on a national scale 133 estuaries (61 require full protection and 72 require partial protection) including those already protected, would be required to meet biodiversity targets (Turpie *et al*., 2012). Of these, 10 falls within the study area, with a subset of 9 estuaries requiring protection (see **Table 12.8** for more detail). Fully protected estuaries are taken to be full no-take areas. Partial protection might involve zonation that includes a no-take area, or it might address other pressures with other types of action. In both these cases, the management objective would be to protect 50% of the biodiversity features of the partially protected estuary. Fully protected and partially protected estuaries can be considered Estuarine Protected Areas, whereas all other estuaries should be designated Estuarine Management Areas. All estuaries require a Management Plan and these plans should be guided by the requirements of the National Estuary Biodiversity Plan.

The national priority list provides recommendations regarding the extent of protection required for each estuary, the recommended extent of the estuary perimeter that should be free from development to an appropriate setback line, and the preliminary REC (or recommended future health class) as required under the National Water Act (**Table 12.7**).

Table 12.7 National priorities, the extent of protection required (Full = full no-take protection (modified from Turpie *et al*., 2012)

#	Estuary	Protected Area	Ramsar site	Important Bird Area	Priority set for conservation (National, provincial or municipal)	NBA Recommended extent of protection	NBA Minimum recommended extent of undeveloped margin	NBA 2011: Provisional Recommended Ecological Category
W11	aMatigulu/iNyoni	●			●	Partial	0.5	A
W13	iSiyaya	●			●	Full	0.5	B
W13	uMlalazi	●		●	●	Full	0.75	A or BAS
W12	uMhlathuze	●		●	●	Partial	0.5	A or BAS
W12	Richards Bay				●	Partial	0.5	A or BAS
W12	iNhlabane					-	-	C
W2	iMfolozi/ uMsunduze	●	●	●	●	Full	0.75	A
W3	St Lucia	●	●	●	●	Full	0.75	A
W7	uMgobezeleni	●			●	Full	0.75	A or BAS
W7	Kosi	●	●	●	●	Full	0.75	A or BAS

All estuaries within the study area, except for iNhlabane, are conservation priorities being either in formally protected areas (i.e. nature reserve, provincial protected area, iSimangaliso Wetland Park and/or UNESCO World Heritage Site) or desired protected area. In addition, three systems are also Ramsar sites and five systems are Important Bird Areas.

12.4 RECOMMENDED ECOLOGICAL CATEGORY (REC)

Given the overall very high estuarine and conservation importance of the estuaries in the region, for all of the estuaries, the REC is predicted to be higher than the PES (**Table 12.8**). Note that the information presented in this section relates to data already available to the study, as PES categories based on 2022 data have not yet been finalized.

In most cases, improvements would have to be achieved through a combination of flow and non-flow related interventions, e.g. control of illegal gillnetting or improving water quality. Where the REC was determined by an EWR study it is indicated by cross-reference to the study on **Table 12.8**, otherwise the REC was determined during NBA (2018). The PES and RECs of the uMhlathuze and iNhlabane historical EFR studies were not listed in **Table 12.8** as these (or any reports derived from these studies) did not follow the prescribed estuary methods in determining the RECs. Given their severe degradation from natural, their RECs will be BAS (likely to be a low D or D/E category).

Both the PES and REC listed in **Table 12.8** will be re-evaluated as part of the EWR/scenario assessment process planned for February 2023.

Table 12.8 A summary of estuary importance, PES and REC, based on existing data

Secondary Catchment	Estuary	Estuary Importance					PES (NBA 2018)	REC
		Estuary Importance Rating	NBA Biodiversity priority	Protected area	DFFE Important Fish Nurseries	Carbon sequester-ation		
W11	aMatigulu/ iNyoni	Important	SA	●	High	Medium	B	A/B[1]
W13	iSiyaya	Low to Average Importance	SA	●	Low	Medium	E	B[2]
W13	uMlalazi	High Importance	SA	●	High	High	B	A/B[3]
W12	uMhlathuze	High Importance	SA	●	High	High	D	BAS (likley D)
W12	Richards Bay	Important	SA		High	High	D/E	BAS (likely D)
W12	iNhlabane	Important	KZN		Medium	High	E	BAS (likely D)
W2	iMfolozi/ uMsunduze	High Importance	SA	●	High	High	D	B[4]
W3	St Lucia	High Importance	SA	●	High	High	D/E	B[4]
W7	uMgobezeleni	Low to Average Importance	SA	●	Low	Medium	B	A/B
W7	Kosi	High Importance	SA	●	High	High	A/B	A[5]

1 DWS (2015a).
2 DWAF (2006).
3 DWS (2015b).
4 DWS (2016a).
5 DWS (2016b).

13 SUMMARY AND CONCLUSIONS

13.1 SUMMARY OF CONFIDENCE

A summary of the confidence in the site assessments is provided in **Table 13.1 – 13.8**. Confidences are defined as follows: 0 = none, 1 = low, 3 = medium, 5 = high.

Table 13.1 EWR MA1: Confidence ratings for assessed components

Hydro-logy	**Confidence Natural**	**Confidence Present Day**	**Comment**	
	2	2	Close inspection of hydrology shows anomalies with the January flows and manipulation was required.	
Hydraulics	**Site character**	**Data**	**Confidence**	
			Low flows	**High flows**
	2	2	2	2
Geo-morphology	**Confidence**	**Morphological indicators**	**Bed material mobility indicators**	
	3.5	Good morphological indicators for flood bench (annual flood) on right and left bank, confirmed by vegetation indicators.	Adequate across transect, based on average velocity and 98% velocity to provide a range of particle size class that can be mobilised based on Hjulstrom's (1935) curve.	
Macro-invertebrates	**Confidence: Rating**	**Low flow EWR confidence: Motivation**		
	2	Low confidence in hydrology reduced confidence in conditions estimated under reference and present day.		
Fish	**Confidence: Rating**	**Low flow EWR confidence: Motivation**		
	2	Low confidence in hydrology reduced confidence in conditions estimated under reference and present day.		
Riparian vegetation	**Confidence: Rating**	**Low flow EWR confidence: Motivation**		
	3	Flow estimations were based on surveyed vegetation levels and associated hydraulics to determine discharge at critical levels. Although the survey data were from 9 years ago, these levels should still be intact and meaningful. Biotic interpretation of required levels is the weakest component of the estimation and remains largely a hypothesis.		
EWR assessment	The modelled naturalised seasonal distribution of flows is different from what would be expected. When setting EWR flows, the seasonal distribution was modified to accommodate a more natural distribution. This does impact on the confidence of the EWR.			

Table 13.2 EWR NS1: Confidence ratings for assessed components

Hydro-logy	**Confidence Natural**	**Confidence Present Day**	**Comment**	
	3	2	All hydrological flows are higher than values measured in 2002, 2013 and 2014.	
Hydraulics	**Site character**	**Data**	**Confidence**	
			Low flows	**High flows**
	2	2	2	1
Geo-m	**Confidence**	**Morphological indicators**	**Bed material mobility indicators**	

	2	Site not visited. Only one clear indicator (annual flood bench) on hydraulic section.	Maximum size class mobilised seems low, based on average velocity and 98% velocity to provide a range of particle size class that can be mobilised based on Hjulstrom's (1935) curve.
Macro-invertebrates	**Confidence: Rating**	**Low flow EWR confidence: Motivation**	
	2	Low confidence in hydrology reduced confidence in conditions estimated under reference and present day.	
Fish	**Confidence: Rating**	**Low flow EWR confidence: Motivation**	
	2	Low confidence in hydrology reduced confidence in conditions estimated under reference and present day.	
Riparian vegetation	**Confidence: Rating**	**Low flow EWR confidence: Motivation**	
	3	Flow estimations were based on surveyed vegetation levels and associated hydraulics to determine discharge at critical levels. Although the survey data were from 9 years ago, these levels should still be intact and meaningful. Biotic interpretation of required levels is the weakest component of the estimation and remains largely a hypothesis.	
EWR assessment	Historic discharge observations on four occasions are substantially lower than Present Day (PD, modelled) values, whereas the PD flow regime is similar to the naturalised (modelled) flow regime (PD slightly higher). Furthermore, the seasonal discharge distribution is markedly different from what is expected. There is consequently hydrological uncertainty. This results in a lower confidence in the determined EWR.		

Table 13.3 EWR WM1: Confidence ratings for assessed components

Hydro-logy	**Confidence Natural**	**Confidence Present Day**	**Comment**	
	4	2	A detailed water requirement assessment is still required in order to determine more accurate present day flows. This is underway.	
Hydraulics	**Site character**	**Data**	**Confidence**	
			Low flows	**High flows**
	2	2	2	3
Geo-morphology	**Confidence**	**Morphological indicators**	**Bed material mobility indicators**	
	3.5	Good morphological indicators for flood bench (annual flood) on left bank and higher bench on right bank, confirmed by vegetation indicators.	Adequate across transect, based on average velocity and 98% velocity to provide a range of particle size class that can be mobilised based on Hjulstrom's (1935) curve.	
Macro-invertebrates	**Confidence: Rating**	**Low flow EWR confidence: Motivation**		
	3	Good quality data on flows (hydraulic), Macro-invertebrates and habflo information and realistic reference flows.		
Fish	**Confidence: Rating**	**Low flow EWR confidence: Motivation**		
	3	Good quality data on flows (hydraulic), fish and habflo information and realistic reference flows.		
Riparian vegetation	**Confidence: Rating**	**Low flow EWR confidence: Motivation**		
	3	Flow estimations were based on surveyed vegetation levels and associated hydraulics to determine discharge at critical levels. Although the survey data were from 9 years ago, these levels should still be intact and meaningful. Biotic interpretation of required levels is the weakest component of the estimation and remains largely a hypothesis.		

Table 13.4 EWR BM1: Confidence ratings for assessed components

Hydro-logy	**Confidence Natural**	**Confidence Present Day**	**Comment**	
	4	2	A detailed water requirement assessment is still required in order to determine more accurate present day flows. This is underway.	
Hydraulics	**Site character**	**Data**	**Confidence**	
			Low flows	**High flows**
	3	2	2	2
Geo-morphology	**Confidence**	**Morphological indicators**	**Bed material mobility indicators**	
	3	Good morphological indicators for flood bench (annual flood) on right bank, confirmed by vegetation indicators.	Adequate across transect, based on average velocity and 98% velocity to provide a range of particle size class that can be mobilised based on Hjulstrom's (1935) curve.	
Macro-invertebrates	**Confidence: Rating**	**Low flow EWR confidence: Motivation**		
	3	Good quality data on flows (hydraulic), Macro-invertebrates and habflo data and realistic reference flows.		
Fish	**Confidence: Rating**	**Low flow EWR confidence: Motivation**		
	3	Good quality data on flows (hydraulic), fish and habflo information and realistic reference flows.		
Riparian vegetation	**Confidence: Rating**	**Low flow EWR confidence: Motivation**		
	3	Flow estimations were based on surveyed vegetation levels and associated hydraulics to determine discharge at critical levels. Although the survey data were from 9 years ago, these levels should still be intact and meaningful. Biotic interpretation of required levels is the weakest component of the estimation and remains largely a hypothesis.		

Table 13.5 EWR MK1: Confidence ratings for assessed components

Hydrology	**Confidence Natural**	**Confidence Present Day**	**Comment**	
	4	2	A detailed water requirement assessment is still required in order to determine more accurate present day flows. This is underway.	
Hydraulics	**Site character**	**Data**	**Confidence**	
			Low flows	**High flows**
	3	2	3	2
Geo-morphology	**Confidence**	**Morphological indicators**	**Bed material mobility indicators**	
	3.5	Good morphological indicators for marginal zone (left bank) and flood bench (annual flood) on right bank and higher bench on left bank, confirmed by vegetation indicators.	Adequate across transect, based on average velocity and 98% velocity to provide a range of particle size class that can be mobilised based on Hjulstrom's (1935) curve.	

Macro-invertebrates	**Confidence: Rating**	**Low flow EWR confidence: Motivation**
	2	Low confidence in hydrology reduced confidence in conditions estimated under reference and present day.
Fish	**Confidence: Rating**	**Low flow EWR confidence: Motivation**
	2	Low confidence in hydrology reduced confidence in conditions estimated under reference and present day.
Riparian vegetation	**Confidence: Rating**	**Low flow EWR confidence: Motivation**
	3	Flow estimations were based on surveyed vegetation levels and associated hydraulics to determine discharge at critical levels. Although the survey data were from 9 years ago, these levels should still be intact and meaningful. Biotic interpretation of required levels is the weakest component of the estimation and remains largely a hypothesis.
EWR assessment	The PD hydrology gives discharges that appear to be too low during the dry season. For this reason, the EWR results were not constrained to PD. This means, however, that EWR flows may be higher than PD (modelled) at times, even though the recommended ecological state does not require an increase in discharge. This results in lower confidence in the determined EWR.	

Table 13.6 EWR UP1: Confidence ratings for assessed components

Hydrology	**Confidence Natural**	**Confidence Present Day**	**Comment**	
	4	2	A detailed water requirement assessment is still required in order to determine more accurate present day flows. This is underway.	
Hydraulics	**Site character**	**Data**	**Confidence**	
			Low flows	**High flows**
	2	2	3	2
Geo-morphology	**Confidence**	**Morphological indicators**	**Bed material mobility indicators**	
	2.5	Lack of a clear indicator for annual flood bench due to disturbance by sand mining, no confirmation from veg. indicator. Left bank not visited. Other levels confirmed by vegetation indicators.	Adequate across transect, based on average velocity and 98% velocity to provide a range of particle size class that can be mobilised based on Hjulstrom's (1935) curve.	
Macro-invertebrates	**Confidence: Rating**	**Low flow EWR confidence: Motivation**		
	3	Good quality data on flows (hydraulic), Macro-invertebrates and habflo and realistic reference flows.		
Fish	**Confidence: Rating**	**Low flow EWR confidence: Motivation**		
	3	Good quality data on flows (hydraulic), fish and habflo and realistic reference flows.		
Riparian vegetation	**Confidence: Rating**	**Low flow EWR confidence: Motivation**		
	3	Flow estimations were based on surveyed vegetation levels and associated hydraulics to determine discharge at critical levels. Although the survey data were from 9 years ago, these levels should still be intact and meaningful. Biotic interpretation of required levels is the weakest component of the estimation and remains largely a hypothesis.		

Table 13.7 EWR AS1: Confidence ratings for assessed components

Hydrology	**Confidence Natural**	**Confidence Present Day**	**Comment**	
	4	3		
Hydraulics	**Site character**	**Data**	**Confidence**	
			Low flows	**High flows**
	3	3	3	2
Geo-morphology	**Confidence**	**Morphological indicators**	**Bed material mobility indicators**	
	2.5	Lack of a clear indicator for annual flood bench, no confirmation from veg. indicator. Left bank not visited. Other levels confirmed by vegetation indicators.	Adequate across transect, based on average velocity and 98% velocity to provide a range of particle size class that can be mobilised based on Hjulstrom's (1935) curve.	
Macro-invertebrates	**Confidence: Rating**	**Low flow EWR confidence: Motivation**		
	3.5	Good quality data on flows (hydraulic), macro-invertebrates and habflo and realistic reference flows. Better recent macro-invertebrate data (IUCMA) to confirm flow indicator species.		
Fish	**Confidence: Rating**	**Low flow EWR confidence: Motivation**		
	3.5	Good quality data on flows (hydraulic), fish and habflo and realistic reference flows. Better recent fish data (IUCMA) to confirm flow indicator species.		
Riparian vegetation	**Confidence: Rating**	**Low flow EWR confidence: Motivation**		
	3	Flow estimations were based on surveyed vegetation levels and associated hydraulics to determine discharge at critical levels. Although the survey data were from 9 years ago, these levels should still be intact and meaningful. Biotic interpretation of required levels is the weakest component of the estimation and remains largely a hypothesis.		

Table 13.8 EWR NG1: Confidence ratings for assessed components

Hydrology	**Confidence Natural**	**Confidence Present Day**	**Comment**	
	4	3		
Hydraulics	**Site character**	**Data**	**Confidence**	
			Low flows	**High flows**
	2	1	2	2
	Site character: Advantages - gauging station located upstream. Disadvantages - located at the downstream end of a steep boulder rapid; two-channels at low flows with a third high flow channel. **Data rating:** One observed low-flow rating point; a high flow strand line from the recent (2021/22) wet season that was linked to a minimum discharge estimate (gauge exceeded its maximum rating). **Low flow:** Depth at which flow ceases is unclear; large scale roughness elements increase uncertainty at discharges lower than measured. **High flow:** Some uncertainty in the high flow energy gradient - cross-section located between a rapid and run.			
Geomorphology	**Confidence**	**Morphological indicators**	**Bed material mobility indicators**	
	2.5	No clear morphological indicators on left bank; limited	Adequate across transect, based on average velocity and 98% velocity to provide a range of	

		vegetation indicators to confirm levels on right bank. (Vegetation specialist did not visit the site.)	particle size class that can be mobilised based on Hjulstrom's (1935) curve.
Macro-invertebrates	**Confidence: Rating**	**Low flow EWR confidence: Motivation**	
	3.5	Good quality data on flows (hydraulic), macro-invertebrates and habflo and realistic reference flows. Better recent macro-invertebrate data (IUCMA) to confirm flow indicator species.	
Fish	**Confidence: Rating**	**Low flow EWR confidence: Motivation**	
	3.5	Good quality data on flows (hydraulic), fish and habflo and realistic reference flows. Better recent fish data (IUCM) to confirm flow indicator species.	
Riparian vegetation	**Confidence: Rating**	**Low flow EWR confidence: Motivation**	
	1	No site visit, had limited surveyed data, and used photographs and geomorphology as guidance.	

13.2 SUMMARY OF ECOCLASSIFICATION AND EWR

A summary of the EcoClassification results and EWR per site is provided in **Table 12.9**.

Table 13.9 Summary of the EcoClassification results and EWR per site

EWR MA1: Matigulu River								
						Coordinates	S29.02010 E31.47040	
						SQ[1] code	W11A-03612	
						RU[2]	RU W11-2	
						IUA[3]	IUA W11	
						Level 2 EcoRegion	17.01	
						Geomorphic Zone[4]	Upper foothills	
PRESENT ECOLOGICAL STATE: PES								
I IHI[4]	**R IHI[5]**	**PC[6]**	**Geom[7]**	**Rip Veg[8]**	**Fish**	**Inverts[9]**	**Instream**	**EcoStatus**
B/C (80%)	**B/C (78%)**	**B (84.5%)**	**B (87%)**	**B/C (79.4%)**	**B (86.4%)**	**B/C (80.9%)**	**B (83.3%)**	**B/C (81.3%)**
ECOLOGICAL IMPORTANCE AND SENSITIVITY								
MODERATE								
RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES								
REC = B/C for ECOSTATUS								
ECOLOGICAL WATER REQUIREMENTS (EWR)								
Natural MAR: 55.17 MCM[11]					Present day MAR: 41.85 MCM			
Low flow EWR					**Total flow EWR**			
MCM		% of nMAR			MCM		% of nMAR	
13.04		23.6			18.75		34	

EWR NS1: Nseleni River								
							Coordinates	S28.63410 E31.92517
							SQ code	W12G-03229
							RU	RU W12-8
							IUA	IUA W12-b
							Level 2 EcoRegion	13.03
							Geomorphic Zone[4]	Lower foothills
PRESENT ECOLOGICAL STATE: PES								
I IHI	**R IHI**	**PC**	**Geom**	**Rip Veg**	**Fish**	**Inverts**	**Instream**	**EcoStatus**
B/C (81%)	**C (70.3%)**	**B (82.7%)**	**B (85%)**	**C (64.4%)**	**C (67.9%)**	**B/C (79.4%)**	**C (74.3%)**	**C (68.4%)**
ECOLOGICAL IMPORTANCE AND SENSITIVITY								
MODERATE								
RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES								
REC = C for ECOSTATUS								
ECOLOGICAL WATER REQUIREMENTS (EWR)								
Natural MAR: 31.23 MCM				Present day MAR: 31.56 MCM				
Low flow EWR				**Total flow EWR**				
MCM		% of nMAR		MCM			% of nMAR	
4.76		17.4		6.85			21.9	

EWR WM1: White Mfolozi River								
							Coordinates	S28.23146 E31.18666
							SQ code	W21H-02897
							RU	RU W21-5
							IUA	IUA W21
							Level 2 EcoRegion	14.05
							Geomorphic Zone[4]	Lower foothills
PRESENT ECOLOGICAL STATE: PES								
I IHI	**R IHI**	**PC**	**Geom**	**Rip Veg**	**Fish**	**Inverts**	**Instream**	**EcoStatus**
B/C (79.3%)	**B/C (77.4%)**	**B (84.5%)**	**B/C (78.8%)**	**B/C (81.3)**	**C (73%)**	**B/C (81.1%)**	**C (77.08**	**B/C (79.2%)**
ECOLOGICAL IMPORTANCE AND SENSITIVITY								
MODERATE								
RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES								
REC = B/C for ECOSTATUS								
ECOLOGICAL WATER REQUIREMENTS (EWR)								

Natural MAR: 222.51 MCM		Present Day MAR: 191.8 MCM	
Low flow EWR		**Total flow EWR**	
MCM	% of nMAR	MCM	% of nMAR
54.74	26.6	89.31	40.1

EWR BM1: Black Mfolozi River		
	Coordinates	S27.93890 E31.21030
	SQ code	W22A-02610
	RU	RU W22-1
	IUA	IUA W22
	Level 2 EcoRegion	3.1
	Geomorphic Zone[4]	Upper foothills

PRESENT ECOLOGICAL STATE: PES								
I IHI	**R IHI**	**PC**	**Geom**	**Rip Veg**	**Fish**	**Inverts**	**Instream**	**EcoStatus**
B/C (77.7%)	**C (74.4%)**	**B/C (81.8%)**	**A (93%)**	**C (74.9%)**	**C (75.9%)**	**B/C (81.2%)**	**B/C (78.9%)**	**C (76.9%)**

ECOLOGICAL IMPORTANCE AND SENSITIVITY
MODERATE
RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES
REC = C for ECOSTATUS

ECOLOGICAL WATER REQUIREMENTS (EWR)			
Natural MAR: 166.72 MCM		Present Day MAR: 144.13 MCM	
Low flow EWR		**Total flow EWR**	
MCM	% of nMAR	MCM	% of nMAR
18.38	11	43.58	26.1

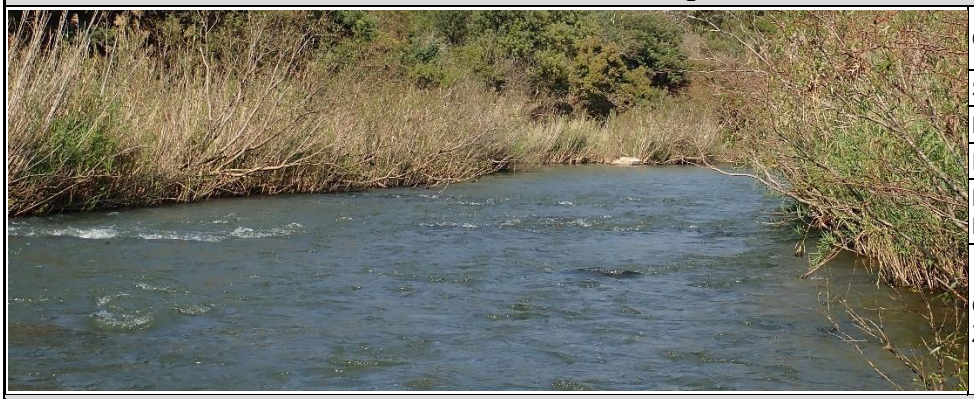
EWR MK1: Mkuze River		
	Coordinates	S27.59210 E32.21800
	SQ code	W31J-02480
	RU	RU W31-5
	IUA	IUA W31-b
	Level 2 EcoRegion	3.08
	Geomorphic Zone[4]	Lowland

PRESENT ECOLOGICAL STATE: PES								
I IHI	**R IHI**	**PC**	**Geom**	**Rip Veg**	**Fish**	**Inverts**	**Instream**	**EcoStatus**
C (66.3%)	**C (72.1%)**	**C/D (58.3%)**	**B (82.26%)**	**C (73%)**	**C (75.4%)**	**C (77.7%)**	**C (76.6%)**	**C (74.8%)**

ECOLOGICAL IMPORTANCE AND SENSITIVITY
HIGH
RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES
REC = B for ECOSTATUS (Impacts non-flow related and flows will be set for a C EC)

ECOLOGICAL WATER REQUIREMENTS (EWR)			
Natural MAR: 158.75 MCM		Present Day MAR: 106.13 MCM	
Low flow EWR		**Total flow EWR**	
MCM	% of nMAR	MCM	% of nMAR
34.74	21.9	58.87	37.1

EWR UP1: Pongola River								
						Coordinates	S27.36413 E30.96962	
						SQ code	W42E-02221	
						RU	RU W42-2	
						IUA	IUA W42-b	
						Level 2 EcoRegion	3.1	
						Geomorphic Zone[4]	lower/upper foothills	
PRESENT ECOLOGICAL STATE: PES								
I IHI	**R IHI**	**PC**	**Geom**	**Rip Veg**	**Fish**	**Inverts**	**Instream**	**EcoStatus**
B/C (80.5%)	**B/C (77.8%)**	**A/B (88.3%)**	**A/B (89.8%)**	**C (70%)**	**C (73.9%)**	**B/C (79.5%)**	**C (77%)**	**C (73.5%)**
ECOLOGICAL IMPORTANCE AND SENSITIVITY								
MODERATE								
RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES								
REC = C for ECOSTATUS								
ECOLOGICAL WATER REQUIREMENTS (EWR)								
Natural MAR: 356.84 MCM				Present Day MAR: 299.39 MCM				
Low flow EWR				**Total flow EWR**				
MCM		% of nMAR		MCM		% of nMAR		
54.84		15.4		97.31		27.3		

EWR AS1: Assegaai River								
						Coordinates	S27.06230 E30.98880	
						SQ code	W51E-02049	
						RU	RU W51-3	
						IUA	IUA W52	
						Level 2 EcoRegion	4.06	
						Geomorphic Zone[4]	lower/upper foothills	
PRESENT ECOLOGICAL STATE: PES								
I IHI	**R IHI**	**PC**	**Geom**	**Rip Veg**	**Fish**	**Inverts**	**Instream**	**EcoStatus**
C/D (59.1%)	**C/D (58.7%)**	**B/C (80.6%)**	**C (70.84%)**	**C (69.9)%**	**C (69.2%)**	**B/C (78.6%)**	**C (77.8%)**	**C (74.16%)**
ECOLOGICAL IMPORTANCE AND SENSITIVITY								
MODERATE								
RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES								
REC = C for ECOSTATUS								
ECOLOGICAL WATER REQUIREMENTS (EWR)								
Natural MAR: 328.61 MCM				Present Day MAR: 164.11 MCM				
Low flow EWR				**Total flow EWR**				
MCM		% of nMAR		MCM		% of nMAR		
40.06		12.2		70.85		21.6		

EWR NG1: Ngwempisi River

Coordinates	S26.679448 E30.70213
SQ code	W53E-01790
RU	RU W53-3
IUA	IUA W52
Level 2 EcoRegion	11.04/4.06
Geomorphic Zone[4]	Upper foothills/ Transitional

PRESENT ECOLOGICAL STATE: PES

I IHI	R IHI	PC	Geom	Rip Veg	Fish	Inverts	Instream	EcoStatus
C (64.3%)	C/D (61.8%)	B (85.5)	B (83.3.%)	B/C (77.4%)	C (72.8%)	B (87.3%)	B/C (80.36%)	B/C (79.8%)

ECOLOGICAL IMPORTANCE AND SENSITIVITY

MODERATE

RECOMMENDED ECOLOGICAL CATEGORY (REC) = PES

REC = B/C for ECOSTATUS

ECOLOGICAL WATER REQUIREMENTS (EWR)

Natural MAR: 156.33 MCM		Present Day MAR: 79.15 MCM	
Low flow EWR		**Total flow EWR**	
MCM	% of nMAR	MCM	% of nMAR
30.46	19.5	50.82	32.5

1 Sub-quaternary reach
2 Resource Unit
3 Integrated Unit of Analysis
4 Instream component of Index of Habitat Integrity
5 Riparian component of Index of Habitat Integrity
6 Physico-Chemical
7 Geomorphology'
8 Riparian Vegetation
9 Macroinvertebrates

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15 APPENDIX A: COMMENTS AND RESPONSE REGISTER

No.	Section	Comment	From	Addressed?
1	Sec. 1.3 Pg 1-2	Indicates that "The sites are summarised in **Table 1.1** and illustrated in **Figure 1.2**." - Figure 1.2 illustrates the Project Plan and not the Sites. Can you please include a map showing IUAs with EWR sites?	M Sekoele	Addressed.
2	Sec. 3.1 Pg 3-2	"The Revised Desktop Reserve Model (RDRM, v2) was used to estimate the EWR requirements for the sites …" Remove the word requirements and add s to EWR.	M Sekoele	Corrected.
3	Sec. 3.1 Pg 3-2	Apply superscript to the th of the 60th and 90th percentiles.	M Sekoele	Corrected.
4	Table 4.5 Pg 4-5	"Similar functions to above in these zones." What does this mean?	M Sekoele	It means that this class flood has the same functions as the previous two. Wording updated for clarification.
5	Sec.12.3.1 Pg 12-5	Check the last sentence of the 1st paragraph: "Table 12.6Table 12.5 summarises the relationship between EIS and their significance (DWA, 2008b)."	M Sekoele	Corrected.
6		1st sentence of the 2nd paragraph: is Table 12.7 correct in this sentence? "Five of the estuaries in the study area are of High ecological importance, namely uMlalazi, uMhlathuze, iMfolozi/uMsunduze St Lucia, and Kosi (**Table 12.7**)."	M Sekoele	Corrected.
7	Sec 10 Pg 10-1	How are cross border flows considered to Eswatini in the EWR estimates?- Applicable to EWR AS1 and NG1	T. Sawunyama	EWRs do not consider cross-border flows or any other user. Once approved, EWRs must be supplied and all users catered for over and above the EWRs.
8		Recent IUCMA biomonitoring data (2020) could have been considered.	T. Sawunyama	As indicated in the report, the IUCMA 2019 data was used. As far as could be established that was the latest available report (monitoring conducted). Although the IUCMA report date is January 2020, the surveys were conducted in 2019 and accurately reflected in the EWR report.
9		Be consistent of number of decimal places you are using.	T. Sawunyama	Corrected.
10	Table 4.8 Pg 4-7	Why using 3 decimal places here?	T. Sawunyama	This is the output of the model.
11	Table 10.1 Pg 10-1	Did you take into consideration of alien vegetation removal upstream of the dam, as IUCMA we had planned to embark on alien vegetation removal but WWF has already started.	T. Sawunyama	PSP team was not aware current and planned removal. However, the IHI applies to the entire RU which is below the dam where aliens also occur.
12	Table 10.1 Pg 10-1	Did you consider IUCMA sampling in 2020 data, available in the Annual status report	T. Sawunyama	As indicated in the report, the IUCMA 2019 data was used. As far as could be established that was the latest available report (monitoring conducted). Although the IUCMA report date is January 2020, the surveys were conducted in 2019 and accurately reflected in the EWR report.
13	Table 11.2 Pg 11-2	WQ source: Upstream forestry and roads network - I would expect sources to be landuse based activities.	T. Sawunyama	The main land use in the RU above the EWR site is forestry, although some nutrient elevation is evident linked to impacts from Amsterdam and its WWTW, and some upstream cultivation. These impact particularly on the Thole

No.	Section	Comment	From	Addressed?
				River, which is one of the two tributaries entering the Ngwempisi upstream of NG1. The IUCMA data regularly collected at this site indicated Good water quality. Wording updated for clarification.
14	Table 11.2 Pg 11-2	Fish: Source: Amsterdam, agriculture, livestock farming, WWTW, informal settlement, catchment erosion, agriculture, dams and weirs, water abstraction. - I would expect this to affect water quality component.	T. Sawunyama	Altered water quality was indicated as a cause in the fish section, although impacts of upstream dams is significant.
15	Table 13.8 Pg 13-5	Check Low Flow EWR confidence of fish.	T. Sawunyama	The IUCMA data was considered, and that is why this site (Ngwempisi) (and the Assegaai also covered by IUCM)) confidence was higher (3.5) than the rest of the sites (confidence of 3) where recent data was not available.
16	Table 7.3 and 10.3	Barbus argentius and Barbus eutaenia change to Enteromius genus.	JM Mazibuko	Corrected
17		Just out of curiosity, I have some few general comments which I am not sure where to put them in the report: 1. For fish, seems like at all the sites only a few species were caught and identified compared to the expected species that are supposed to be in the area/catchment. This is because of altered habitat/flows, etc. Why is the PES for fish so high then? 2. In some instances no indicator species have been selected, so what will then be used or monitored to check if there have been no changes or even improvements? 3. The REC that has been set, is it based on the current situation or based on the improving the system and ensuring that there's restoration of the critical habitat for fish, etc.	JM Mazibuko	1. I think this question was also asked during the training presentation and I answered it then in detail. Bottom line is that during any single fish survey at a single site, all fish species will not be sampled. Continued and regular monitoring is required for this, something that is lacking in RSA. When considering the PES the specialist must consider habitat derived observations and consider all impacts at the site to estimate which species should still be present (although not sampled). A species should only be excluded if there is evidence that it was lost from a reach (due to impacts). Fish indices required detailed interpretation by a fish specialist and is not similar to indices such as SASS5 that is only based on the taxa sampled/observed. 2. Indicator species are used as part of the EWR study to specifically calculate flows (typically rheophilic species). When monitoring a system different indicators should be used to monitor different aspects or impacts. These are typically set during the EcoSpecs phase. 3. The REC is based on set rules, including aspects such as the EI and ES, to decide if the PES should be improved or maintained.
18	Whole report	Pages viii, ix and x under the summary section. The section of the Table that I highlighted in red should read "MCM" instead of "% of nMAR". This applies to the Tables for the following EWR sites: EWR WM1, EWR BM1, EWR MK1, EWR UP1, EWR AS1 and EWR NG1. The same error is found in the tables located on pages 13-6 to 13-10	R. Pillay	Corrected.
19	Whole report	Page 4-7 - The Heading of section 4.6 "**EWR MA1 RECOMMENDATIONS FOR A B/C EC".** I suggest writing Ecological Category in full instead of the abbreviation EC else the array of the capital letters might create confusion when	R. Pillay	Corrected.

No.	Section	Comment	From	Addressed?
		reading it. The same comment is application to the other sections of the Report (i.e. Sections 5.6, 6.6, 7.6, 8.6, 9.6, 10.6 and 11.6).		
	Sec 5.6 Pg 5-7	Under, the sentence "**The low flow EWR** is 4.7 MCM and equates to 17.4% of the nMAR". According to the Table in the summary section, this percentage is 15.2%.	R. Pillay	Corrected.
	Sec 6.6 Pg 6-6	Under section 6.6, the sentence "**The low flow EWR** is 54.741. MCM and equates to 26.6% of the nMAR". According to the Table in the summary section, this percentage is 24.6%.	R. Pillay	Corrected.
	Sec 9.9 Pg 9.9	Under section 9.6, the sentence "**The low flow EWR** is 58.84 MCM and equates to 15.4% of the nMAR. " According to the Table in the summary section, the low flow EWR should be 54.84 MCM.	R. Pillay	Corrected.
	Pages x and 13-9	The Table for **EWR AS1: Assegaai River**, the cell referring to the REC = C for ECOSTATUS should be highlighted in green.	R. Pillay	Corrected.