

DETERMINATION OF WATER RESOURCE CLASSES, RESERVE AND RESOURCE QUALITY OBJECTIVES STUDY FOR SECONDARY CATCHMENTS A5 – A9 WITHIN THE LIMPOPO WATER MANAGEMENT AREA (WMA 1) AND SECONDARY CATCHMENT B9 IN THE OLIFANTS WATER MANAGEMENT AREA (WMA 2)

EWR REPORT: RIVER ASSESSMENT

VOLUME 2 – DATA COLLECTION AND ANALYSIS

FINAL DRAFT

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DOCUMENT INDEX

Reports that will be produced as part of this project are indicated below.

The bold type indicates this report.

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01	WEM/WMA01&02/00/CON/RDM/0122	Inception Report
02	WEM/WMA01&02/00/CON/RDM/0222	Water Resources Information Gap Analysis Report
03	WEM/WMA01&02/00/CON/RDM/0322	Delineation and Status Quo Report
04	WEM/WMA01&02/00/CON/RDM/0422	Linking the value and condition of the Water Resources Report
05	WEM/WMA01&02/00/CON/RDM/0522	Site Selection and verification EWR Report
06a	WEM/WMA01&02/00/CON/RDM/0123a	EWR Report – River Assessment (Volume 1) – EcoCategorisation
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06c	WEM/WMA01&02/00/CON/RDM/0123c	EWR Report – River Assessment. (Volume 3) – Ecological Water Requirements
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08b	WEM/WMA01&02/00/CON/RDM/0323b	Wetland Assessment Volume 2 – EWR of Nylsvley and Makuleke Floodplain Wetlands
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11	WEM/WMA01&02/00/CON/RDM/0324	Scenarios evaluation and Draft Water Resource Classes Report
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13	WEM/WMA01&02/00/CON/RDM/0225	Evaluation of Resource Unit Report
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ACRONYMS

Acronyms	Description
ADP	Acoustic Doppler Profiler
ASPT	Average Score Per Taxon
AT	Air Temperature
BM	Bench Marks
Ca	Calcium
CEV	Chronic Effect Value
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
Cl	Chloride
DDT	Dichlorodiphenyltrichloroethane
DO	Dissolved Oxygen
DRIFT	Downstream Response to Imposed Flow Transformations
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
EC	Ecological Category
EI	Ecological Importance
ES	Ecological Sensitivity
EWR	Ecological Water Requirement
FPOM	Fine Particulate Organic Matter
FRAI	Fish Response Assessment Index
FROC	Frequency of Occurrence
FSC	Full Supply Capacity
GAI	Geomorphological Driver Assessment Index
GSM	Gravel, Sand and Mud
GVA	Gross Value Added
GWS	Government Water Scheme
HABFLO	HABitat FLOw simulation model
HCB	Hexachlorobenzene
HYF	Historical Yield Firm
IUA	Integrated Unit of Analysis
KNP	Kruger National Park
LM	Local Municipality
MAR	Mean Annual Runoff
MCB	Macro channel banks
MIRAI	Macroinvertebrate Response Assessment Index
Na	Sodium
NCMP	National Chemical Monitoring Programme
NEMP	National Eutrophication Monitoring Programme
NH_4-N	Ammonium Nitrogen

Acronyms	Description
NO_3+NO_2-N	Nitrate and Nitrite Nitrogen
NTMP	National Toxicity Monitoring Programme
NTU	Nephelometric Turbidity Units
PAI	Physico-chemical Assessment Index
PCB	Polychlorinated biphenyls
PCDD	PolyChlorinated Dibenzo-p-Dioxins
PCDF	PolyChlorinated DibenzoFurans
PES	Present Ecological State
pH	Potential of Hydrogen
PO_4-P	Orthophosphate
Pop	Population
POPs	Persistent Organic Pollutants
REC	Recommended Ecological Category
RWS	Rural Water Scheme
RWSS	Rural Water Supply Schemes
SASS5	South African Scoring System version 5.0
SCPOPs	Stockholm Convention on Persistent Organic Pollutants
SIC	Stones-in-current
SnA	Southern Africa
SO_4	Sulphate
SOOC	Stones-out-of-current
TDS	Total Dissolved Solids
TIN	Total Inorganic Nitrogen
TPC	Threshold of Potential Concern
TWQR	Target Water Quality Range
UNEP	United Nations Environment Programme
VEGRAI	Riparian vegetation response assessment index
VIC	Vegetation-in-current
VOOC	Vegetation-out-of-current
WMA	Water Management Area
WQ	Water Quality
WRPM	Water Resources Planning Model
WRSM	Water Resources Simulation Model
WRYM	Water Resources Yield Model
WT	Water Temperature
WTW	Water Treatment Works
WWTW	Waste Water Treatment Works

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1 INTRODUCTION

1.1 Background

The Department of Water and Sanitation (DWS), Chief Directorate (CD): Water Ecosystems Management (WEM) initiated a three-year study, extended to a fourth year, to Determine Water Resource Classes, the Reserve and Resource Quality Objectives for Secondary Catchments A5-A9 in the Limpopo Water Management Area (WMA 1) and Secondary Catchment B9 in the Olifants Water Management Area (WMA 2). This project aligns with the Department's mandate to protect water resources as stipulated in Chapter 3 of the National Water Act.

1.2 Overview of study area

The focus of the integrated Water Resource Class, Reserve and RQO Study is Limpopo WMA Secondary Catchments (SC) A5 – A9 and B9 in the Olifants WMA. The area spans six main river catchments: Lephalala, Mogalakwena, Sand, Nzhelele and Luvuvhu in the Limpopo WMA and the Shingwedzi in the Olifants WMA. The rivers in the Limpopo WMA drain into the internationally shared Limpopo River Basin between South Africa, Botswana, Zimbabwe and Mozambique.

1.3 Purpose of this report

This is the Ecological Water Requirement (EWR) Report – River Assessment (Volume 2) Data collection and analysis Report. It is one of three EWR Reports for rivers that describes the work to determine the EWRs for rivers:

- EWR Report – River Assessment (Volume 1) EcoCategorisation
- **EWR Report – River Assessment (Volume 2) Data Collection and Analysis (this report)**
- EWR Report – River Assessment (Volume 3): Ecological Water Requirements.

In this report the data collated, collected and analysed and used to determine the Present Ecological Status (PES), Ecological Importance (EI) and Ecological Sensitivity (ES) and Recommended Ecological Category (REC) (Volume1) and the EWR (Volume 3) are described for each discipline. The disciplines assessed are:

- Hydrology (**Section 2**)
- Hydraulics (**Section 3**)
- Water quality (**Section 4**)
- Geomorphology (**Section 5**)
- Riparian vegetation (**Section 6**)
- Aquatic macroinvertebrates (**Section 7**)
- Fish (**Section 8**)
- Ecological Impportance and Sensitivity (**Section 9**)
- Socio-economics (**Section 10**).

1.4 EWR sites

There are 14 river EWR sites **(Table 1.1)** that were assessed during this study.

Table 1.1: Location and co-ordinates of the river EWR sites

NO.	NODE	RIVER	EWR (DRIFT) code	IUA (Quaternary catchment)	LATITUDE	LONGITUDE
1	Riv11	Lephalala	1_Lephalala	Upper Lephalala (A50B)	23º59'11"S	28º24'20"E
2	Rvi1	Rietfontein	2_Rietfontein	Kalk pan se loop (A63C)	22°34'06"S	28°37'31"E
3	Ri1	Olifantspruit	3_Olifantspruit	Upper Nyl/Sterk (A61B)	24º39'46"S	28º28'31"E
4	Ri5	Mogalakwena	4_Mogalakwena1	Upper Nyl/Sterk (A62B)	23º54'55"S	28º43'59"E
5	Ri14	Mogalakwena	5_Mogalakwena2	Mogalakwena (A63A)	23°09'05"S	28°40'44"E
6	Riv32	Kolope	6_Kolope	Mapungubwe (A63E)	22º13'50"S	29º14'56"E
7	Ri20	Sand	7_Sand	Upper Sand (A71D)	23º22'03"S	29º35'41"E
8	Ri27	Nzhelele	8_Nzhelele	Nzhelele/Ṅwaneḍi (A80G)	22º28'52"S	30°15' 45”E
9	Ri28	Ṅwaneḍi	9_Ṅwaneḍi	Nzhelele/Ṅwaneḍi (A80J)	22°30'50"S	30º26'52"E
10	Riii6	Latonyanda	10_Latonyanda	Upper Luvuvhu (A91D)	23º02'51"S	30º13'54"E
11	Ri30	Mutshindudi	11_Mutshindudi	Upper Luvuvhu (A91G)	22º53'18"S	30º35'18"E
12	Ri32	Luvuvhu	12_Luvuvhu	Upper Luvuvhu (A91H)	22º45'42"S	30º53'41"E
13	Ri33	Mutale	13_Mutale1	Lower Luvuvhu/Mutale (A92B)	22º40'26"S	30º42'11"E
14	Ri34	Mutale	14_Mutale2	Lower Luvuvhu/Mutale (A92D)	22º26'17"S	31º04'39"E

2 HYDROLOGY

2.1 Climate

The climate of the study area is temperate and semi-arid in the south to arid in the north. Rainfall usually occurs in summer with thunderstorms and is strongly influenced by the topography.

Mean annual rainfall ranges from 800 mm in the mountainous regions of the Waterberg to 300mm near the Limpopo River. The eastern parts of the study area (catchments A9 and B9) have their headwaters located in the mountainous regions of the Soutpansberg where mean annual rainfall is about 1000mm, dropping to 400mm in the lower reaches of the catchment.

Potential evaporation is well in excess of rainfall and runoff is low due to the prevalence of sandy soils. The water resources, especially surface water resources, are heavily stressed due to the present levels of development.

2.2 Water supply infrastructure

Most of the dams are in the higher rainfall areas (**Figure 2.1**). The characteristics of the major dams, including the historic firm yield (HFY) are provided in **Table 2.1**.

Table 2.1: Characteristics of the major dams in the study area

Dam	Catchment	Quaternary	MAR[(1)] (Mm^3/a)	FSC (Mm^3)	HFY[(2,3)] (Mm^3/a)
Donkerpoort	Mogalakwena	A61A	5.3	2.4	1.44
Doorndraai		A61H	38.1	44.2	9.64
Glen Alpine		A62J	204.0	18.9	7.09
Turfloop	Sand	A71B	0.6	3.3	0.01
Houtrivier		A71E	0.4	7.5	0.06
Nzhelele	Nzhelele	A80C	73.4	51.2	16.81
Mutshedzi		A80A	15.5	2.2	1.98
Luphephe		A80H	21.4	14.8	6.87
Ṅwanedi		A80H	9.5	5.3	1.54
Albasini	Luvuvhu	A91B	14.56	28.2	5.0
Vondo	Mutshinḍuḍi	A91G	132.75	30.45	16.8
Ṅanḍoni	Luvuvhu	A91F	30.82	116.2	62.0 [(5)]
Lake Fundudzi	Mutale	A92A	114.92	21.5	
Makuleke	Shingwedzi	B90B	10.08	13.0	0.1
Ḍamani/Mvuwe	Mbwedi	A91G	132.75	12.9	4.8
Ṁambedi	Luvuvhu	A91C	57.72	4.5	
Mukumbani	Mutale	A92A	114.92	3.9	
Tshakhuma	Latonyanda	A91D	48.12	2.47	1.4
Phiphiḍi	Mutshinḍuḍi	A91G	132.75	0.19	0.2

Notes: (1) MAR simulated in the WRSM2000 model with active groundwater abstractions.
(2) HFY based on analysis of 91 years from the 1920 to the 2010 hydrological years.
(3) Yields are before meeting EWR water requirements.
(4) MAR based on WRSM2012 model for the 1920 to the 2009 hydrological years
(5) System yield of Ṅanḍoni without EWR

The Donkerpoort Dam is a small dam in the upper Mogalakwena River basin supplying Modimolle, but cheaper water is purchased from the Roodeplaat Dam Transfer Scheme, so this dam is under-utilised.

The Doorndraai Dam supplies the Mokopane LM and irrigation users downstream. Lepelle Northern Water bought some of the irrigation allocation in 1990 and Lonmin Mine bought the remainder as no growth in irrigation has taken place since several irrigation farmers have switched to game farming recently.

Glen Alpine Dam was constructed to supply irrigation users along the Mogalakwena River. Water for irrigation is released down the river resulting in very high river losses (78%, DWS 2017). There is no canal or conveyance system in place to minimise this loss. There are an estimated 5.67 million m^3 lost per annum. There are abstraction weirs downstream to store releases.

The Turfloop and Houtrivier dams are small dams located in the Sand River basin to supply rural settlements near Polokwane.

The Mutshedzi Dam was built to supply domestic water to Louis Trichardt Town and surrounds. Water is released for irrigation users and 5.65 million m^3/a is allocated to domestic users.

The Nzhelele Dam as well as the Ṅwaneḓi and Luphephe twin dams in the Nzhelele River basin were constructed to supply irrigators. The Nzhelele Dam is over-allocated, weirs catch releases made and there are significant losses due to illegal connections, aged infrastructure and reticulation leaks. Approximately 60% of the water released from the Dam is lost along the Nzhelele Canal.

The Ṅwaneḓi and Luphephe twin dams are situated inside the Ṅwaneḓi Nature Reserve, at the confluence of the Ṅwaneḓi and Luphephe Rivers. These dams provide water for wildlife and irrigation. Water is released from the dam into a canal system for irrigators. The Cross Dam downstream is used as a balancing dam. There is an allocation of 1.135 million m^3/a to the domestic water requirements of the Luphephe Ṅwaneḓi Regional Water Scheme. These dams are over-allocated.

The Ṋanḏoni Dam and Xikundu Weir together with the existing Albasini, Vonḏo, Phiphiḓi and Tshakhuma Dams and the associated bulk purified water supply are known as the Luvuvhu River Government Water Scheme (GWS). The scheme is managed as an integrated system to supply water for domestic/industrial, irrigation and for the ecological component of the Reserve. Current planning is that the Ṋanḏoni system will in future supply partly or fully a large number of Rural Water Supply Schemes (RWSS). Ḏamani, Mambedi and Frank Ravele dams are also part of the Luvuvhu River system, but are used to supply local water requirements and are therefore managed independently. The Mambedi Dam was severely damaged during a flood event and is no longer in use.

The Xikundu/Malamulele sub-system consists of three weirs and respective water works, which are the Mhinga Weir and Treatment Works, Malamulele Weir and Treatment Works and Xikundu Weir and Treatment Works. They cover the Tshifuḓi RWS, Lambani RWS, North Malamulele East RWS and South Malamulele East RWS.

Significant irrigation developments from surface and groundwater upstream of Albasini Dam resulted in a decrease in the yield available from the Albasini Dam. The irrigation scheme downstream of the

Albasini Dam is seldomly supplied with water from the dam and the dam struggles to meet the urban/industrial demand of Louis Trichardt.

Lake Fundudzi is a natural lake with no obvious outlet and is formed from water off the Mutale River. The Lake is sacred to the Venḓa people, however deforestation, agriculture and development are causing the lake to silt up. The Lake does not supply domestic or agricultural uses.

There are no major dams in the Shingwedzi, due to the limited water resources and the non-availability of suitable dam sites. Some small dams have, however been constructed in the Kruger National Park for game watering. Water for a small area of irrigation is sourced from the Makuleke Dam on the Mphongolo River a tributary of the Shingwedzi River.

The water resources in the Mutale catchment are underdeveloped. Mukumbani Dam is the only dam in the upper reaches of the Tshirovha River to supply Mukumbani Tea Estate. The Vondo North Rural RWS and the Ḓamani RWS are both partly located in the Mutale catchment and are supplied with water from the Vondo and Ḓamani Dams respectively, in the Luvuvhu River catchment. The remainder of the Rural Water Supply Schemes are supplied from Mutale surface (50%) and groundwater resources (50%).

Diffuse water resources in the study area are small storage dams and river abstractions that contribute to the yield of the system, used for irrigation, stock watering, game farming and recreational purposes. Farmers and some rural communities' also abstract water directly from rivers. **Table 2.2** summarises the diffuse water resources and availability in the study area.

Table 2.2: Summary of diffuse water resources

Catchment	FSC (Mm^3)	Available supply from dams and run-of river (Mm^3/a)
Lephalala	18.3	46.5
Mogalakwena	59.1	39.9
Sand(1)	44.2	56.3
Nzhelele	2.5	15.9
Luvuvhu	113.5	131.8

Note: (1) This includes an allocation of 10.96 million m^3/a from the sand aquifers along the Limpopo River near Musina

Due to the arid nature of the study area and the limited surface water available a number of transfers (**Table 2.3**) from neighbouring catchments and WMAs into the study area exist (**Figure 2.1**). No transfers are made out from the study area.

Water users in each quaternary catchment (base water use taken at 2012) are summarised in **Table 2.4.**

Table 2.3: Summary of existing water transfer schemes

Transfer scheme	Source catchment	Recipient catchment	Volume @ 2010 (Mm^3/a)
Ebenezer Dam - Polokwane	Luvuvhu and Letaba	Sand River	12.00(1)
Dap Naude Dam – Polokwane	Luvuvhu and Letaba	Sand River	6.53
Olifantspoort Weir – Polokwane	Olifants	Sand River	11.30(2)
Albasini Dam – Louis Trichardt	Luvuvhu and Letaba	Sand River	2.40
Roodeplaat Dam - Modimolle	Crocodile West	Mogalakwena	1.93
Propose transfers			
Klipvoor-Modimolle and Mookgopong	Crocodile West	Mogalakwena	6.6
ORWRDP: Flag Boshielo-Mokopane	Olifants	Mogalakwena	50.0
Additional water via the Olifantspoort WMA	Olifants	Sand	17.3 – 26.2
Nandoni – Matoks pipeline	Luvuvhu and Letaba	Sand	4.66 – 5.5
Nandoni – Louis Trichardt	Luvuvhu and Letaba	Sand	5.5 – 8.5

Note: (1) The allocation has been increased to 16.2 million m^3/a from 2016.

(2) Refers only to the water transferred to the portion of the Polokwane LM located in the study area, the total allocation is 14.6 million m^3/a.

Table 2.4: Summary of water users in each quaternary catchment (Red. = streamflow reduction, Dem. = irrigation demand)

Quaternary catchment	Invasive Alien Plants		Forest		Irrigation		Domestic and industry	Large dams	Farm dams
	Area (Km^2)	Red. (Mm^3/a)	Area (Km^2)	Red. (Mm^3/a)	Area (Km^2)	Dem. (Mm^3/a)	Dem. (Mm^3/a)	FSC (Mm^3)	FSC (Mm^3)
A50A	3.9	0.37	-	-	12.31	8.43	-		4.66
A50B	0.77	0.07	-	-	1.82	1.33	-		1.5
A50C	7.9	0.75	-	-	2.12	1.31	-		1.56
A50D	-	-	-	-	-	-	-		0.84
A50E	-	-	-	-	12.9	10.83	-		2.6
A50F	-	-	-	-	0.32	0.29	-		0.32
A50G	-	-	-	-	1.9	1.62	-		0.18
A50H	-	-	-	-	15.41	14.68	-		3.39
A50J	-	-	-	-	-	-	-		3.29
A61A	5.6	0.17	-	-	2.97	2.06	2.05	2.4	1.07
A61B	5.65	0.17	-	-	0.37	0.25	0.87		0.42
A61C	7.93	0.25	-	-	2.07	1.3	-		1.03
A61D	2.65	0.08	-	-	0.26	0.17	0.49		0.4
A61E	-		-	-	0.06	0.05	0.41		0.94
A61F	39.34	1.23	-	-	0.57	0.22	3.25	5.14	2.36
A61G	8.82	0.27	-	-	0.78	0.49	0.14		4
A61H	3.37	0.11	-	-	22.36	14.92	-	46.22	12.17
A61J	5.98	0.19	-	-	11.55	5.22	0.58	6.81	6.22
A62A	2.53	0.08	-	-	2.42	2.12	-		1.75
A62B	-		-	-	-	-	-		0.02
A62C	-		-	-	-	-	-		-
A62D	-		-	-	-	-	-		0.66
A62E	1.03	0.03	-	-	-	-	0.13		-
A62F	-		-	-	0.24	0.15	-		0.39
A62G	-		-	-	-	-	-		-
A62H	-		-	-	-	-	-		-
A62J	-		-	-	-	-	-	18.89	15.95
A62K	-		-	-	-	-	-		-
									1.23
A63A	-		-	-	1.49	1.28	-		0.16

Quaternary catchment	Invasive Alien Plants		Forest		Irrigation		Domestic and industry	Large dams	Farm dams
	Area (Km^2)	Red. (Mm^3/a)	Area (Km^2)	Red. (Mm^3/a)	Area (Km^2)	Dem. (Mm^3/a)	Dem. (Mm^3/a)	FSC (Mm^3)	FSC (Mm^3)
A63B	-		-	-	3.85	2.68	-		1.23
A63C	-		-	-	-	-	-		2.67
A63D	-		-	-	2.22	2.41	-		0.59
A63E	-		-	-	-	-			7.07
A71A	20.13	0.15	-	-	2.66	2.04	-	2.6	4.71
A71B	14.46	0.11	-	-	-	-	-	3.3	-
A71C	56.71	0.42	0.96	0.01	2.88	2.01	-		9.82
A71D	5.21	0.04	-	-	0.33	0.22	-		0.21
A71E	15.77	0.12	-	-	0.41	0.14	0.29	15.74	1.98
A71F	2.3	0.02	-	-	0.98	0.37	-		4.55
A71G	3.57	0.03	-	-	0.68	0.34	-		1.69
A71H	16.16	0.12	8.15	0.77	0.47	0.25	-		3.8
A71J	-		-	-	4.51	3.3	-		0.32
A71K	-		-	-	0.55	0.51	-	1.32	9.5
A71L	-		-	-	-	-	-		-
A72A	-	-	-	-	1	0.55	-		1.68
A72B	-	-	-	-	0.4	0.22	-		-
A80A	-	-	17.61	1.8	-	-	1.34	2.16	0.09
A80B	3.73	0.13	1.42	0.15	0.78	0.38	0.96		0.11
A80C	3.89	0.14	-	-	-	-	0.19	51.23	-
A80D	-	-	0.18	0.02	0.27	0.09	-		0.05
A80E	9.74	0.35	0.09	0.01	0.13	0.08	0.34		0.02
A80F	-	-	-	-	5.58	4	0.11		-
A80G	15.85	0.56	-	-	19.94	14.9	0.18		2.17
A80H	25.79	0.92	-	-	-	-	1.55	20.11	-
A80J	-	-	-	-	-	-	-	2.6	0.03
A91A	6.2	0.6	39.4	3.7	5.3	4.9	1.9	-	0.17
A91B	2.9	0.1	1.6	0.1	2.9	2.9	-	3.5	1.66
A91C	-	-	26.7	4.5	19.3	17	-	-	1.79
A91D	-	-	39.6	7.6	9.3	6.7	1.4	0.4	0.5
A91E	-	-	8.6	1.7	-	-		1.7	0.17
A91F	-	-	-	-	3.4	3.2	3.5	166.1	0.16
A91G	6.3	1.1	22.9	2.4	-	-	17.7	31	0.43
A91H	-	-	0.8	0	-	-	3.9	-	0.13
A91J	-	-	-	-	-	-	-	-	0.02
A91K	-	-	-	-	-	-	-	-	-
A92A	-	-	23.2	4.4	-	-	2.2	2.2	0.02
A92B	-	-	-	-	-	-	-	-	-
A92C	-	-	-	-	-	-	-	-	0.78
A92D	-	-	-	-	-	-	-	-	0.3
B90A	-	-	-	-	-	-	-		-
B90B	-	-	-	-	-	-	-	2.2	2.38
B90C	-	-	-	-	-	-	-	0.9	0.9
B90D	-	-	-	-	-	-	-	-	-
B90E	-	-	-	-	-	-	-	-	-
B90F	-	-	-	-	-	-	-	-	2.18
B90G	-	-	-	-	-	-	-	-	0.67
B90H	-	-	-	-	-	-	-	-	1.31

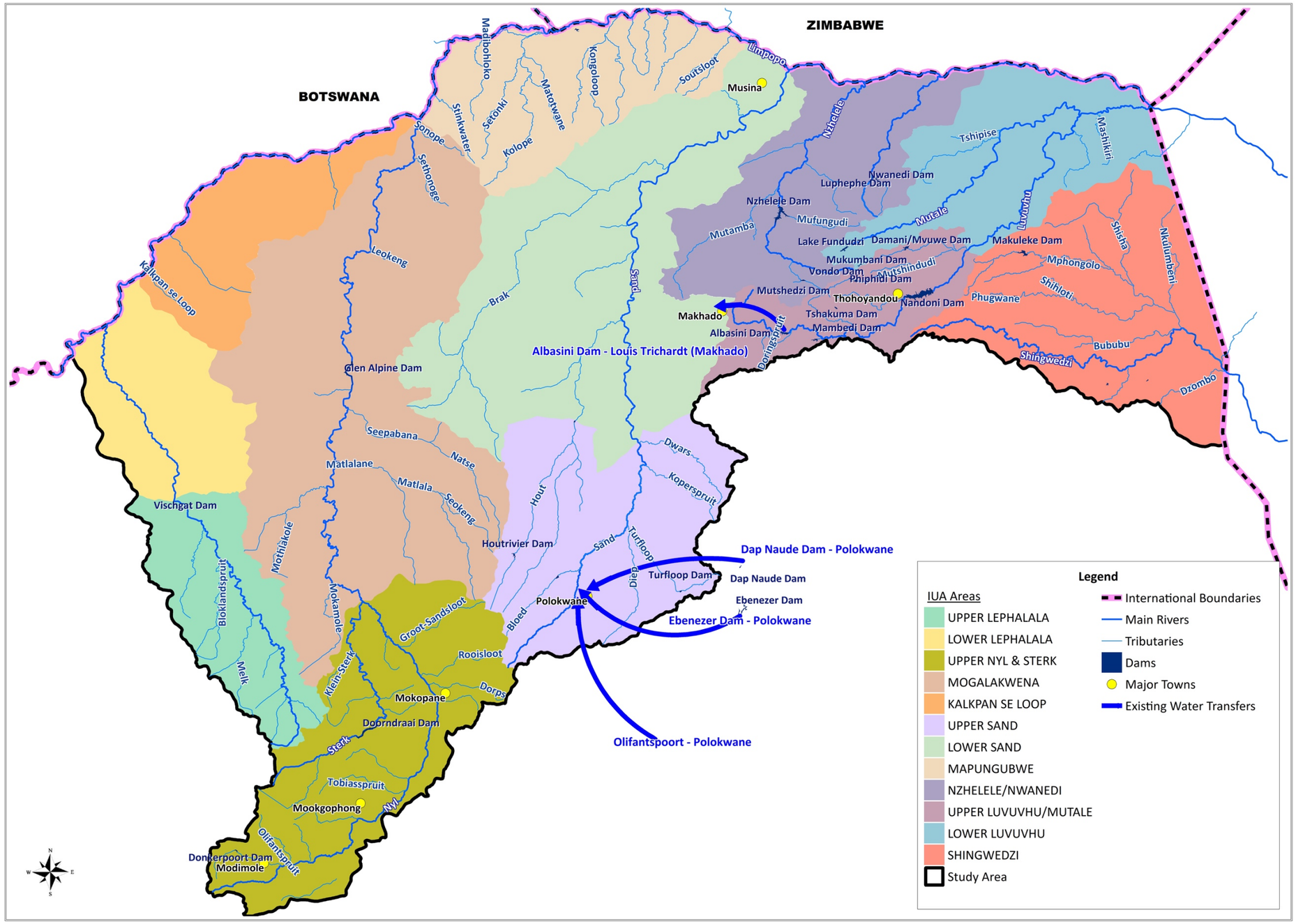


Figure 2.1: Dams and water transfers into the Limpopo River basin

2.3 Hydrological modelling

There have been numerous hydrological studies done in the study area that used the WRSM model. A summary of the relevant water resources models and studies is provided in **Table 2.5**.

The two most recent (AECOM 2015 and WRP 2014) with separate historical configurations for each river basin were used. The historical configurations were adapted to create a naturalised and PES (2022) configuration that were checked by stepping through each operation and performing a mass balance.

Table 2.5: Summary of relevant water resources models and studies

Date	Study Name	Project Area applicable	Model Configured	Hydrology period	Comment
2012	Water Resources of South Africa, 2012 (WR2012)	Full study area	WRSM No system model	1920-2011	WR2012 configurations can be used if other studies are not available
2014	Development of a Reconciliation Strategy for the Luvuvhu and Letaba Water Supply System. Hydrology Report (WRP, 2014)	A9 and B9	WRSM WRYM and WRPM	1920-2011	Both the WRSM and WRYM are available for use (WRSM preferred)
2015	Limpopo Water Management Area North Reconciliation Strategy Hydrological Analysis Report (AECOM,2015)	A5, A6, A7, A8	WRSM WRYM and WRPM	1920-2011	Both the WRSM and WRYM are available for use (WRSM preferred)
2021	DWS Verified Data portal	Full study area	-	Up to 2021	Daily observed data to be used in the disaggregation process has been downloaded

Several improvements were undertaken:

- Introduced demands on large dams where they were missing (such as Nandoni Dam). This information was obtained from the WR2012 Model.
- Replaced observed releases with modelled flows (for instance, the model was configured to use measured releases below Doorndraai Dam).
- Added in major tributaries in correct sequence (e.g. A92D did not flow into A91K).
- Fragmented the configurations to generate flows at each quaternary outlet (e.g. Moved A72B flow to below A72A).

The corrected hydrological models were then used to summarise the natural and current day mean annual runoff (MAR) at each quaternary outlet (**Table 2.6**).

There were several issues identified and corrected:

- Replaced catchment areas with the appropriate area. In most configurations the most downstream quaternary catchment area was the full quaternary catchment. This should have been the catchment relevant to the main river and not included small tributaries flowing directly into the Limpopo River.
- Included the catchment that crosses the South African border (in B90 the configurations only include the catchment on the South African side). This affected B90E and B90H.

- Investigated and rectified the many farm dams with no demands. These were either livestock or domestic demands (for example, in quaternary catchment B90F there was an on-channel dam of 2.18 Mm^3 with no demand located near townships that was likely domestic supply).
- Recalibrated the models paying attention to low flows. For example, the Sand River (A71) model output had elevated low flows because of modelled return flows and no periods of zero flow.

Table 2.6: Hydrological model output summarising natural and current day mean annual flows (Mm3) at quaternary (Quat.) catchment outlets in the study area

Quat.	Naturalised (Mm^3)	PES (2022) (Mm^3)	Quat.	Naturalised (Mm^3)	PES (2022) (Mm^3)	Quat.	Naturalised (Mm^3)	PES (2022) (Mm^3)
A50A	32.3	22.7	A61A	0.4	0.2	A62A	14.2	11.6
A50B	67.1	55.3	A61B	21.9	20.5	A62B	157.3	95.0
A50C	81.8	67.4	A61C	17.1	13.7	A62C	161.4	97.5
A50D	102.1	87.1	A61D	25.6	19.3	A62D	4.5	3.4
A50E	121.1	94.9	A61E	32.5	23.8	A62E	3.7	3.3
A50F	130.6	103.8	A61F	52.0	36.0	A62F	4.7	3.7
A50G	134.7	107.4	A61G	71.9	52.3	A62G	176.9	109.9
A50H	136.6	94.0	A61H	39.9	10.4	A62H	4.1	3.6
A50J	4.8	3.6	A61J	59.5	21.1	A62J	185.6	104.3
A63A	191.9	109.5	A71A	10.3	28.0			
A63B	196.0	110.0	A71B	7.3	8.2	A91A	21.6	7.2
A63C	3.0	2.4	A71C	25.7	42.4	A91B	32.4	12.5
A63D	198.3	111.2	A71D	25.7	42.9	A91C	73.4	20.8
A63E	3.5	1.9	A71E	3.7	1.9	A91D	64.4	47.5
			A71F	6.0	2.8	A91E	69.4	66.1
A80A	49.4	43.0	A71G	10.1	4.6	A91F	254.0	159.6
A80B	66.0	58.3	A71H	47.1	56.8	A91G	128.8	106.4
A80C	75.7	42.1	A71J	63.3	70.1	A91H	409.7	289.2
A80D	7.0	6.8	A71K	90.4	92.2	A91J	415.9	295.5
A80E	14.1	13.1	A71L	7.5	5.9	A91K	574.6	442.8
A80F	99.7	65.9						
A80G	105.4	77.6	A72A	11.3	11.3	A92A	105.5	94.5
A80H	32.2	26.9	A72B	17.3	17.0	A92B	150.3	138.8
A80J	34.6	28.4				A92C	4.6	4.5
						A92D	155.5	144.1
B90A	7.2	7.2	B90D	34.0	31.2			
B90B	11.9	9.3	B90E	5.9	5.9	B90G	34.6	33.9
B90C	9.0	9.0	B90F	19.1	18.6	B90H	91.3	87.5

The next two tasks undertaken were to:

- Extend the hydrology from 2010 to the 2021 hydro year using the CHIRPS database. This also included extending all the current-day water-use demands assuming that current day demands have not increased during this extension period.
- Fragment the model to the nodes and the EWR sites (where nodes were not located at quaternary catchment outlets).

2.4 Generating hydrological time series'

The two main hydrological tasks were:

- To generate long-term (1920-2021) monthly time series at the 75 nodes, to be used in the analysis of the Classification scenarios.
- To generate time series' of daily flows at the EWR sites.

The use of monthly time series' at the 75 nodes will be explained in the Ecologically Sustainable Base Configuration Report, as this is work that will be done for the Classification process. In short it involves fragmenting the WRSM runoff model using incremental node area.

This report describes the construction of daily-flow time series' scenarios for the EWR assessment done in DRIFT-Limpopo.

In order to create daily flow time series' (output from the WRSM) the monthly flows were disaggregated using appropriate daily flow records with sufficiently reliable and long enough records (**Table 2.7**). An important part of this task was to patch missing daily data using regressions where possible. Several flow gauges including some located outside the study area were used because they were close to some of the EWR sites and had long reliable records. The gauges used in disaggregation and patching are listed in **Table 2.7**. Where the simulated monthly hydrological time series (1920-2021) was disaggregated with a shorter daily record from a flow gauge (which only start between 1950 and 1980), months that did not have an overlapping daily record were disaggregated by statistically selecting an appropriate month from the daily record (based on similar volumes).

Four scenarios were constructed:

- Naturalised, used the current day existing configuration with PES (2022) water use, transfers and abstractions removed.
- PES (2022), used the existing 2012 configuration and was updated with 2021 demands in domestic water supply, mines and Waste Water Treatment Works return flows.
- Future scenario 1, used the PES (2022) with projected future demands to 2050.
- Future scenario 2, used Future scenario 1 adjusted for a severe dry future climate.

The hydrological characteristics of the four scenarios are summarised in the River EWR Assessment Report (Volume 3) with the information and data used to create the future use and climate change scenarios.

2.5 Deriving an ecological category for hydrological state

The Mean Annual Runoff (MAR) of the current day flows at each site were divided by the naturalised nMAR to derive an Ecological Category for hydrology at each EWR site using the percentage scores of the EcoCategerisatoin modules. The scores and Ecological Category derived are given in **Table 2.8**.

Table 2.7: Summary of flow gauge record length and % missing data

Station no.	Quaternary Catchment	Available record period			Percentage Missing Data
		Start	End	Years	%
A4H002	A42C	1948/03	2021/03	73	4.3
A4H004	A41C	1962/08	2021/03	59	0.6
A4H005	A42F	1962/08	2021/03	59	2.1
A4H007	A42H	1962/09	2021/03	59	10.3
A4H008	A42D	1964/08	2021/04	57	0.3
A5H004	A50B	1955/12	2021/02	66	1.0
A5R001	A50E	1968/02	2021/03	53	2.2
A5R002	A50G	1968/02	2021/03	53	4.1
A6H009	A63D	1960/06	1997/02	37	4.3
A6H010	A61C1	1964/08	2021/03	57	1.2
A6H011	A61A3	1966/11	2021/03	55	1.3
A6H012	A61B1	1966/11	2021/11	55	0.4
A6H027(A6R001)	A61J	1953/03	2021/03	68	2.1
A6H029(A6R002)	A63A	1970/04	2021/03	51	0.3
A6H033	A61F	1990/11	2021/03	31	0.0
A6H036	A61J	1995/02	2021/06	26	2.0
A7H001	A71H	1957/07	2000/01	43	13.0
A7H003	A71G	1947/10	1995/11	48	8.4
A7H004	A71K	1955/06	1992/07	37	16.3
A7H008	A71K	1992/07	2021/03	29	3.4
A8H8/15 (A8R1)	A80F	1948/02	2021/03	73	1.0
A8H009(A8R002)	A80H	1946/01	2021/03	75	1.0
A9H004	A92A	1932/07	2004/06	72	
A9H007	A91D	1961/08	2000/02	39	0.8
A9H012	A91H	1987/11	2021/06	34	4.2
A9H013	A92D	1988/11	2021/10	33	22.5
A9H025	A91G	1995/10	2012/06	17	7.2
B9H001	B90D	1960/08	2021/06	60	7.7
B9H002	B90F	1984/02	2021/10	37	1.2
B9H003	B90B	1983/11	2013/02	30	0.2
B5H002	B52G	1948/09	1980/01	31	3.9
B8H008	B81J	1959/10	2021/08	60	14.1
B8H018	B83D	1984/03	2021/09	37	12.6
B8H034	B83A	1988/10	2021/09	33	22.7

Table 2.8: Ecological Categories and scores for hydrology

Site	1_Lephalala	2_Rietfontein	3_Olifantspruit	4_Mogalakwena	5_Mogalakwena	6_Kolope	7_Sand	8_Nzhelele	9_Ṅwaneḑi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale	14_Mutale
Naturalised (MCM)	67.6	0.2	8.1	73.4	193.3	2.1	27.4	99.7	33.5	64.3	127.9	398.5	149.7	154.9
Current (MCM)	56.2	0.1	7.6	53.9	114.3	1.1	23.5	59.6	26.6	47.6	105.5	247.8	138.6	143.6
%nMAR	83	76	94	74	59	51	86	60	80	74	82	62	93	93
Category	B	C	A	C	C/D	D	B	C/D	B/C	C	B	C	A	A

3 HYDRAULICS

3.1 Introduction

From an EWR assessment perspective, the relevant outputs from hydraulic modelling are rating relationships for the cross-sections at the EWR sites. These, together with cross-section geometry, are used to produce text tables of ecologically-relevant hydraulic parameters (termed 'indicators' in DRIFT-Limpopo) as a function of discharge, such as maximum (max.) and average depth; max. and average velocity; surface width and/or wetted-perimeter; and velocity-depth classes (which are an ecologically meaningful 'combined' hydraulic-habitat indicator that can be used for quantifying changes in available hydraulic habitat).

3.2 Data collection

Field surveys to the EWR sites were undertaken in August 2022 (low flow) and February 2023 (high flow) following guidance provided in Rowlston and Birkhead (2008) and Birkhead 2010.

The main activities carried out at each of the EWR sites during the low flow field trip in early August 2022:

- Cross-sections were positioned with due consideration of the requirements for EWR determination for ecohydraulics, riverine vegetation, fluvial geomorphology, fish and macro-invertebrates; cross-sectional photographs were taken, as illustrated in **Figure 3.1 to Figure 3.3**.
- Fixed stations were installed (or bench marks; BMs) in the form of steel pegs set within cement beacons and/or marked rocks/fixed structures (e.g., low-level causeways); all fixed stations were photographed to assist potential future re-location.
- Where necessary, vegetation was trimmed to allow a line-of-sight along the cross-sections.
- Cross-sections were surveyed laterally between the top of the macro-channel banks, and included all major changes in slope; water levels (both banks); vegetation; and recent high flow strand lines, where observed.
- Longitudinal water surface slopes were surveyed extending upstream and downstream of the cross-sections, and
- Discharge measurements were performed using the velocity-area method or stage readings were taken where local gauging stations exist, as illustrated in **Figure 3.4**.

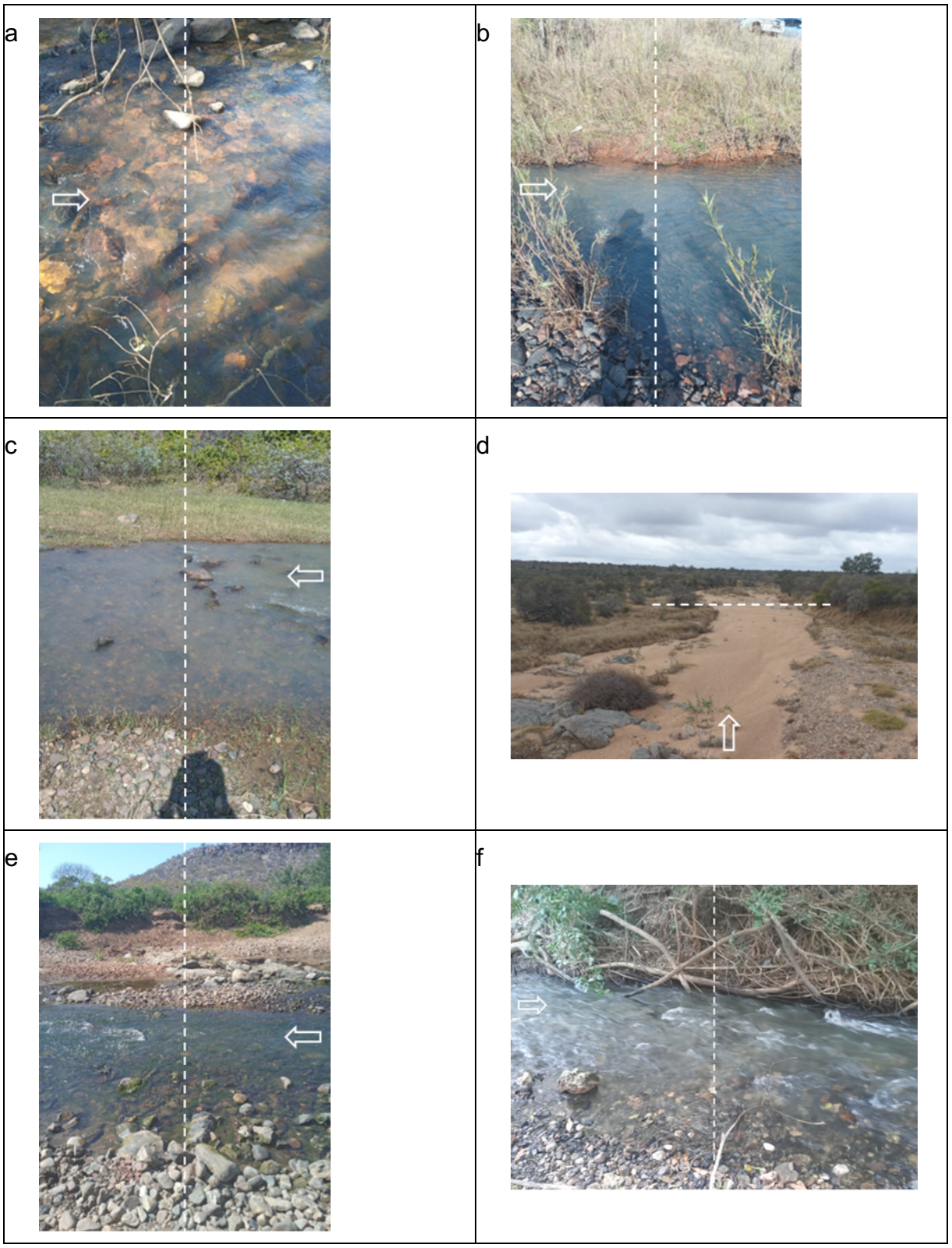


Figure 3.1: Views across the rivers at the EWR sites indicating where cross-sections were surveyed on the a) 3_Olifantspruit, b) 4_Mogalakwena1, c) 5_Mogalakwena2, d) 7_Sand, e) 8_Nzhelele and f) 9_Ṅwanedi; arrows indicate flow directions

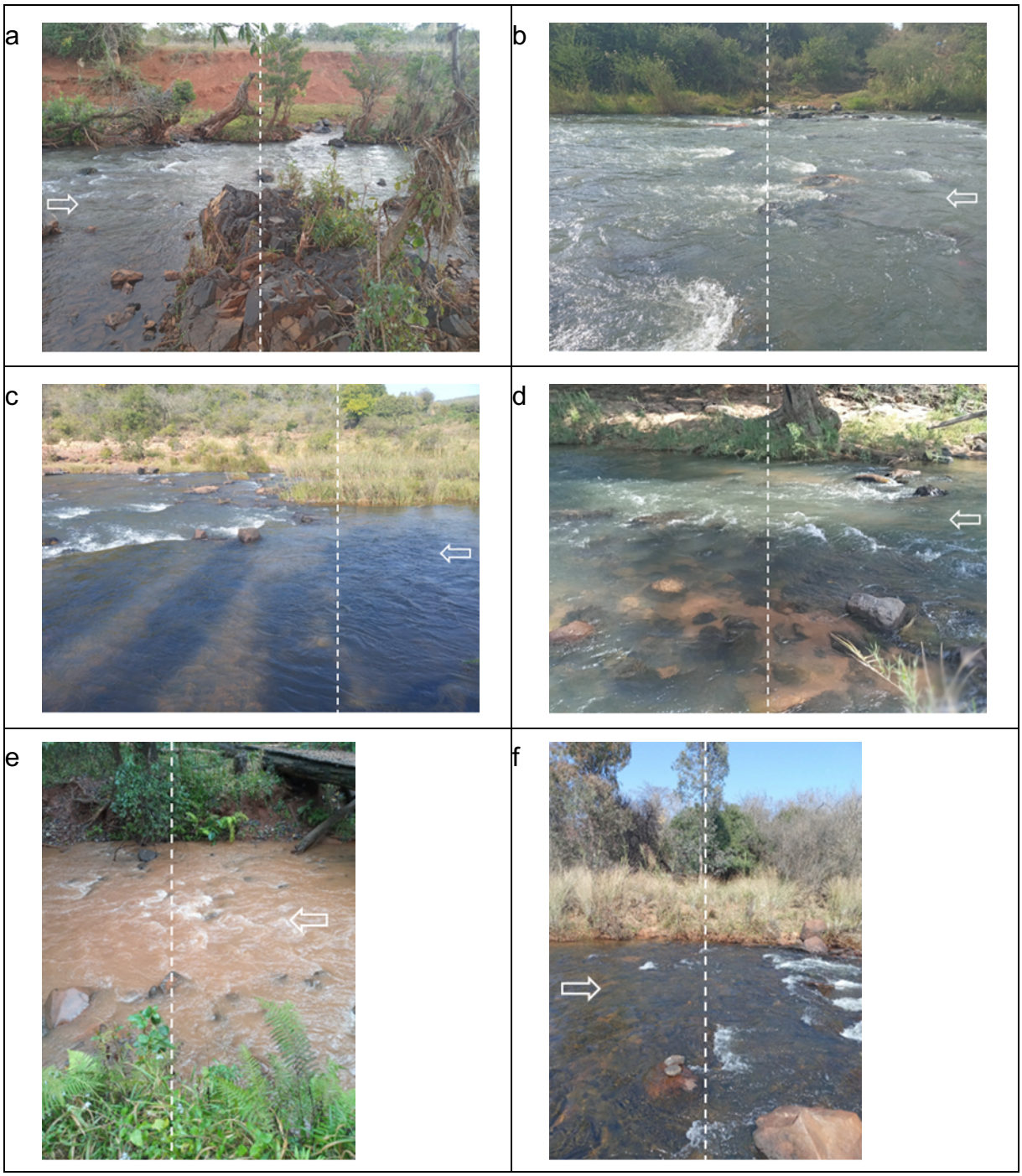


Figure 3.2: Views across the rivers at the EWR sites indicating where cross-sections were surveyed on the a) 11_Mutshindudi, b) 12_Luvuvhu, c) 13_Mutale1, d) 14_Mutale2, e) 10_Latonyanda and f) 1_Lephalala; arrows indicate flow directions

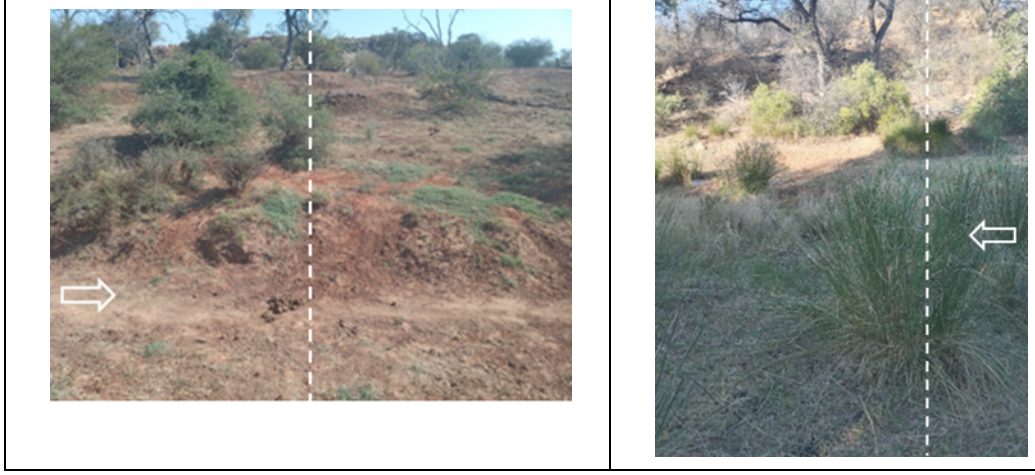


Figure 3.3: Views across the rivers at the EWR sites indicating where cross-sections were surveyed on the a) 6_Kolope and b) 2_Rietfontein; arrows indicate flow directions

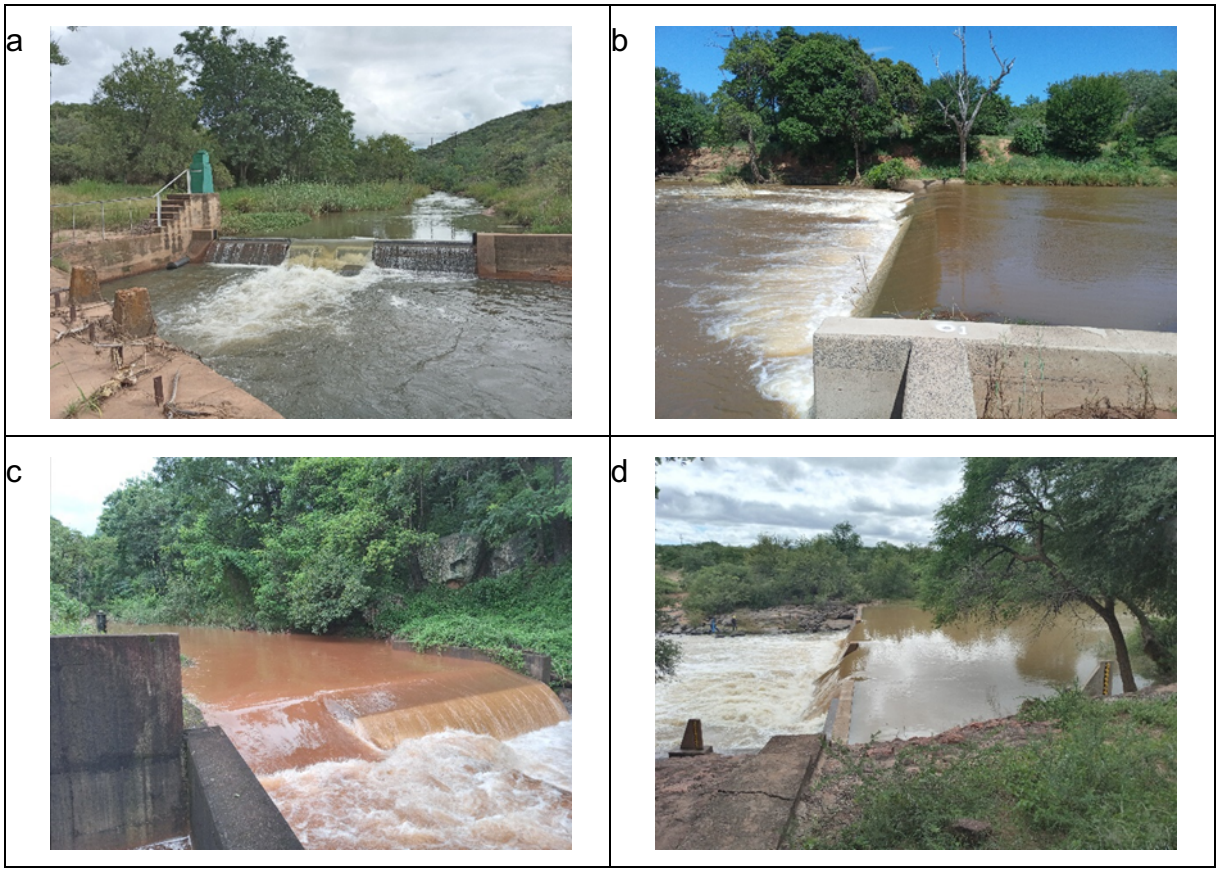


Figure 3.4: DWS hydrometric stations located close to EWR sites: a) A6H012 on the Olifantspruit, b) A9H012 on the Mutale, c) A6H027 on the Latonyanda and d) A6H029 on the Mogalakwena Rivers (photographs taken February 2023)

A second data collection field trip was carried out in late February 2023 (high flow), with the following main activities:

- Water level/stage was surveyed on the previously surveyed cross-section relative to the fixed stations or bench marks.
- Strand/debris line levels were surveyed that indicate the peak flood levels reached during recent high flow events (eg. **Figure 3.5**), which may potentially be correlated to discharges from local DWS hydrometric stations.
- Water levels upstream and downstream of the cross-section were surveyed to allow calculation of the slope/gradient.
- Photographs of the site were taken, and
- Discharge measurements were taken either using the velocity-area method or Acoustic Doppler Profiler (ADP; **Figure 3.6**) at or near the site, or from a local DWS hydrometric station (eg. **Figure 3.4**).

Measured rating data for the cross-sections at the EWR sites are provided in **Table 3.1**, together with the dates of survey.

a



b



Figure 3.5: Examples of floating debris deposited at the EWR sites at 3_Olifantspruit (a) and 1_Lephalala (b), which indicate peak water levels during recent flood events.

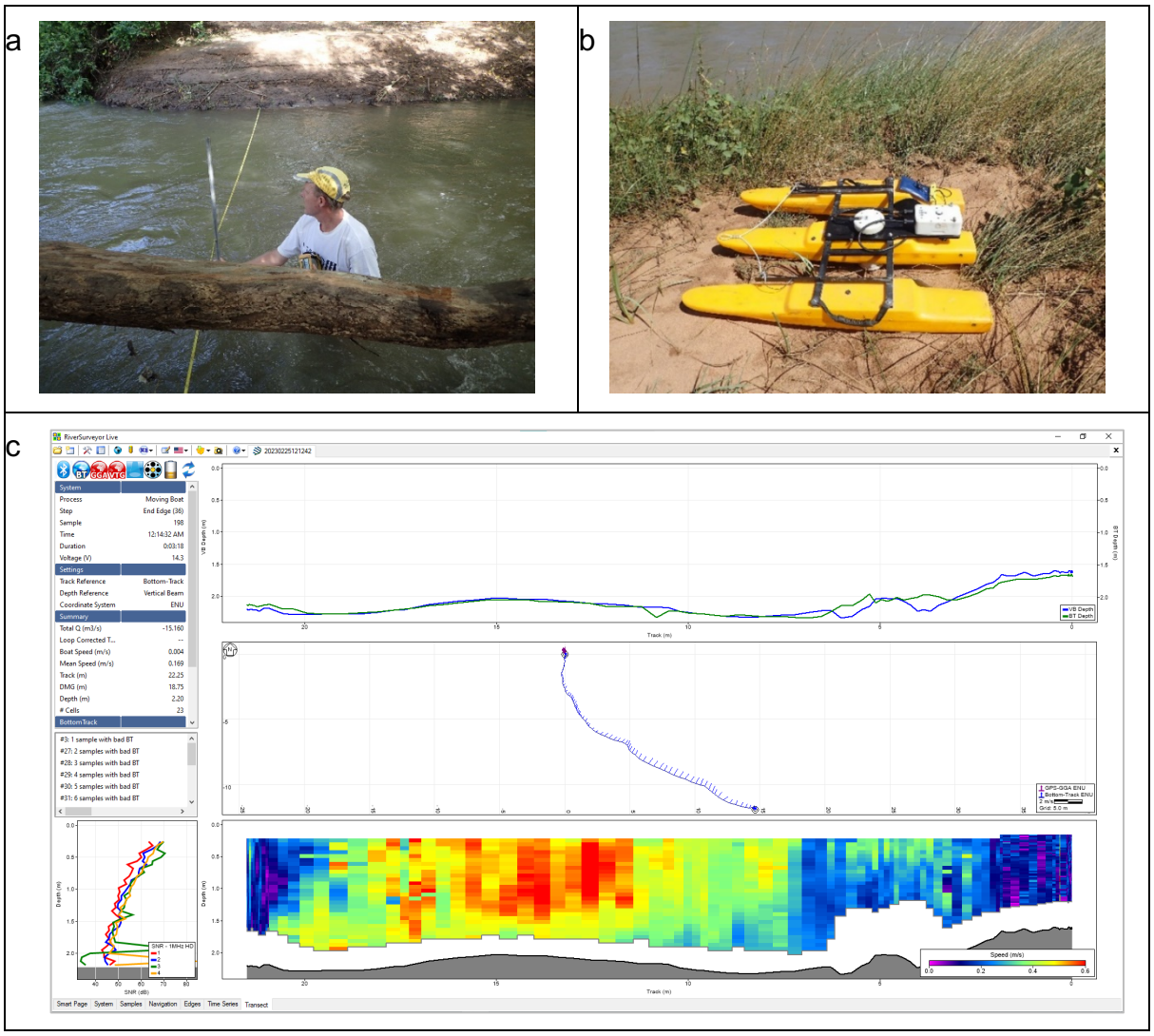


Figure 3.6: Manual discharge measurement using an OTT C31 current meter and the velocity-area method, b) Sontek ADP used at or near selected EWR sites to measure discharge - the trimaran is towed across the river from an inflatable boat or is attached to a rope which is used to guide the trimaran between river banks, c) example graphical output of ADP measurement for 9_Nzhelele

Table 3.1: Measured rating data for the cross-sections at the EWR sites

EWR Site		River	EWR (DRIFT) CODE	Date	Discharge (m^3/s)	Depth[1] (m)
nr	id					
1	Riv11	Lephalala	1_Lephalala	01/2022[a]	234	2.95
				08/08/2022	0.98	0.39
				11/02/2023[a]	87	2.45
				21/02/2023	8.5	0.88
2	Rvi1	Rietfontein	2_Rietfontein	06/08/2022	not measurable[2]	
				27/02/2023	not measurable	
3	Ri1	Olifantspruit	3_Olifantspruit	08/08/2022	0.073	0.28
				20/02/2023	1.4	0.61
4	Ri5	Upper Mogalakwena	4_Mogalakwena1	07/08/2022	0.16	0.25
				21/02/2023	9.9	1.16
5	Ri14	Middle Mogalakwena	5_Mogalakwena2	07/08/2022	0.22	0.24
				27/02/2023	32	1.08
6	Riv32	Kolope	6_Kolope	06/08/2022	no flow	
				26/02/2023	no flow	
7	Ri20	Sand	7_Sand	01/08/2022	no flow	
				22/02/2023	0.6	0.57
8	Ri27	Nzhelele	8_Nzhelele	03/08/2022	0.17	0.27
				25/02/2023	15	0.99
9	Ri28	Ṅwaneḍi	9_Ṅwaneḍi	05/08/2022	0.4	0.31
				25/02/2023	2.9	0.62
10	Riii6	Latonyanda	10_Latonyanda	02/08/2022	1	0.41
				04/02/2023[a]	22	1.47
				22/02/2023	5.2	21.5
11	Ri30	Mutshindudi	11_Mutshindudi	02/08/2022	0.95	0.38
				23/02/2023	18	1.14
12	Ri32	Luvuvhu	12_Luvuvhu	04/2021[a]	297	3.2
				03/08/2022	3.5	0.54
				02/2023[a]	159	3.2
				23/02/2023	69	1.89
13	Ri33	Middle Mutale	13_Mutale1	03/08/2022	2	0.66
				23/02/2023	26	1.16
14	Ri34	Lower Mutale	14_Mutale2	03/08/2022	2.7	0.63
				24/02/2023	34	1.33

[a] strand line flood level correlated with discharge recorded at local DWS hydrometric station

3.3 Analyses and modelling

Rating relationships of the form given by Equation 3.1 were fitted using a combination of measured and modelled rating data. Modelled data were synthesized for medium-to-high flows using one-dimensional hydraulic analyses for uniform flow, with estimates of the energy gradients and resistance coefficients. The '*c*' coefficient in Equation 3.1 represents the depth of zero discharge, which was set to zero for all surveyed cross-sections. It is thus important that cross-sections are located through locally-steep gradients to increase the likelihood that water does not 'pool' at the cessation of flow (ie. $y(0) > 0$). This increases the certainty in extrapolated rating relationships for low flows, by introducing an additional rating point through the *Q*-*y* origin (refer to **Figure 3.7a**). The rating coefficients for the cross-sections

[1] maximum depth as measured from the lowest elevation along the cross-sectional profile
[2] the flow at the EWR site at the time of survey was artesian groundwater from an upstream borehole

at the EWR sites are listed in **Table 3.2**, and are plotted in **Figure 3.7 to** Error! Reference source not found., together with the cross-sectional profiles through rapid, riffle or run features.

$$y = a\,Q^{\,b} + c \qquad \text{Equation 3.1}$$

where y is the max. flow depth (m); Q is discharge (m^3/s); and a, b and c are rating coefficients determined by regression.

Table 3.2: Rating coefficients for the cross-sections at the EWR sites

EWR Site		River	EWR (DRIFT) CODE	Geomorphological feature	Discharge Q (m^3/s)	Rating coefficient (Equation 3.1)		
nr	id					a	b	c
1	Riv11	Lephalala	1_Lephalala	rapid / riffle	≤ 4.28	0.393	0.377	0
					> 4.28	0.381	0.399	0
2	Rvi1	Rietfontein	2_Rietfontein	run	all	0.441	0.376	0
3	Ri1	Olifantspruit	3_Olifantspruit	riffle	≤ 1.40	0.558	0.264	0
					> 1.40	0.325	0.522	0.223
4	Ri5	Upper Mogalakwena	4_Mogalakwena1	riffle	≤ 38.72	0.494	0.372	0
					> 38.72	0.268	0.435	0.612
5	Ri14	Middle Mogalakwena	5_Mogalakwena2	riffle	≤ 32.65	0.379	0.302	0
					> 32.65	0.229	0.424	0.081
6	Riv32	Kolope	6_Kolope	run	all	0.66	0.358	0
7	Ri20	Sand	7_Sand	run	all	0.266	0.449	0
8	Ri27	Nzhelele	8_Nzhelele	riffle	≤ 15.05	0.451	0.29	0
					> 15.05	0.33	0.418	-0.037
9	Ri28	Ṅwanedi	9_Ṅwanedi	riffle	≤ 2.90	0.427	0.35	0
					> 2.90	0.329	0.485	0.068
10	Riii6	Latonyanda	10_Latonyanda	riffle	≤ 0.66	0.41	0.28	0
					> 0.66	0.068	0.914	0.342
11	Ri30	Mutshindudi	11_Mutshindudi	riffle	≤ 17.68	0.387	0.374	0
					> 17.68	0.258	0.501	0.044
12	Ri32	Luvuvhu	12_Luvuvhu	riffle	≤ 69.00	0.319	0.42	0
					> 69.00	0.007	1.129	1.054
13	Ri33	Middle Mutale	13_Mutale1	run / rapid	≤ 18.92	0.567	0.22	0
					> 18.92	0.087	0.6	0.575
14	Ri34	Lower Mutale	14_Mutale2	riffle	≤ 27.48	0.469	0.296	0
					> 27.48	0.11	0.6	0.45

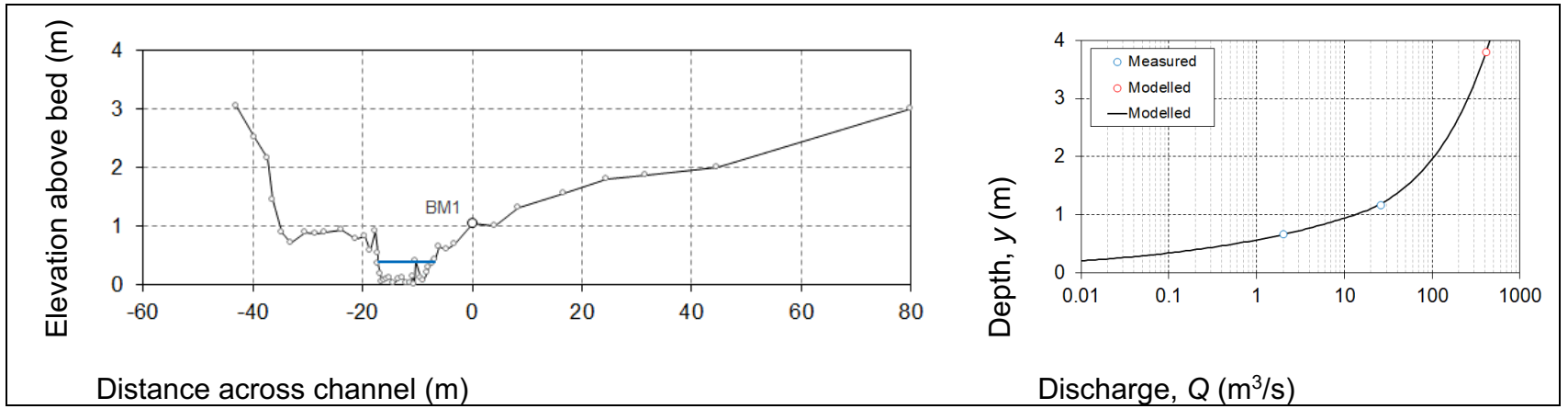


Figure 3.7: Cross-section and rating plots for the riffle cross-sections at 1_Lephalala

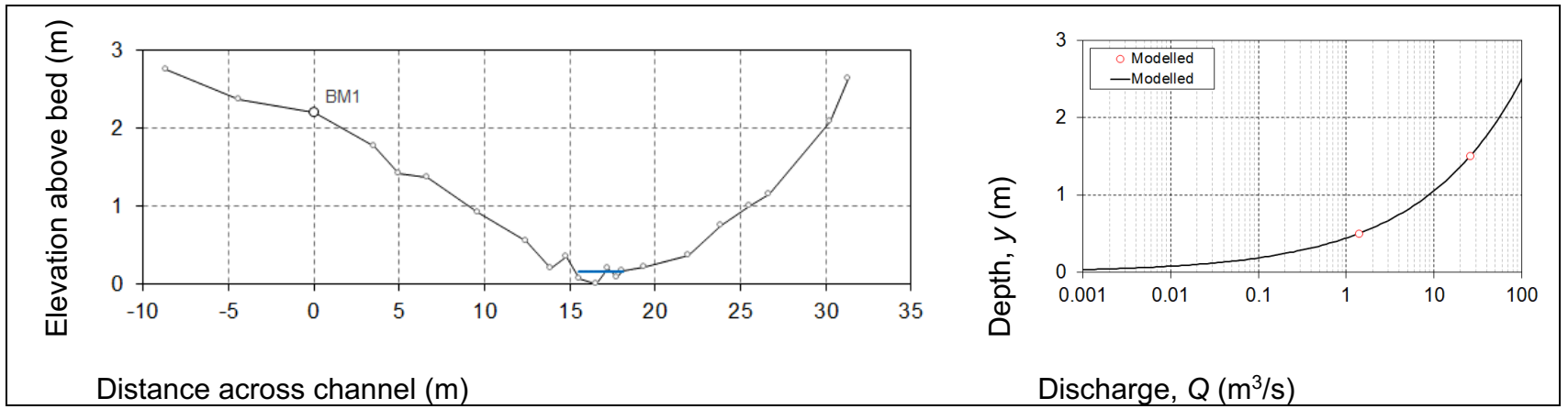


Figure 3.8: Cross-section and rating plots for the riffle cross-sections at 2_Rietfontein

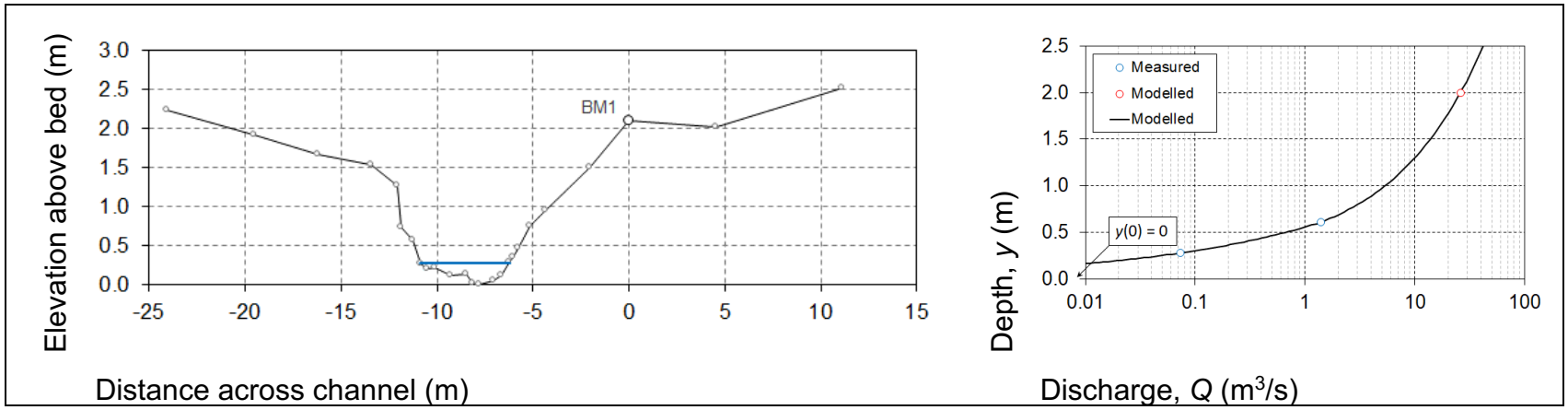


Figure 3.9: Cross-section and rating plots for the riffle cross-sections at 3_Olifantspruit

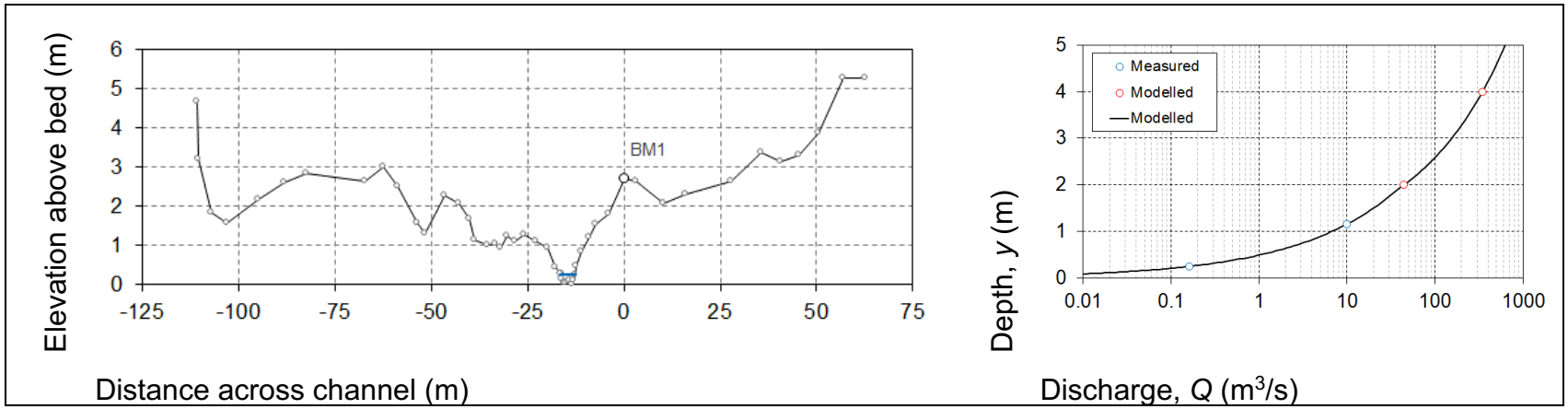


Figure 3.10: Cross-section and rating plots for the riffle cross-sections at 4_Mogalakwena1

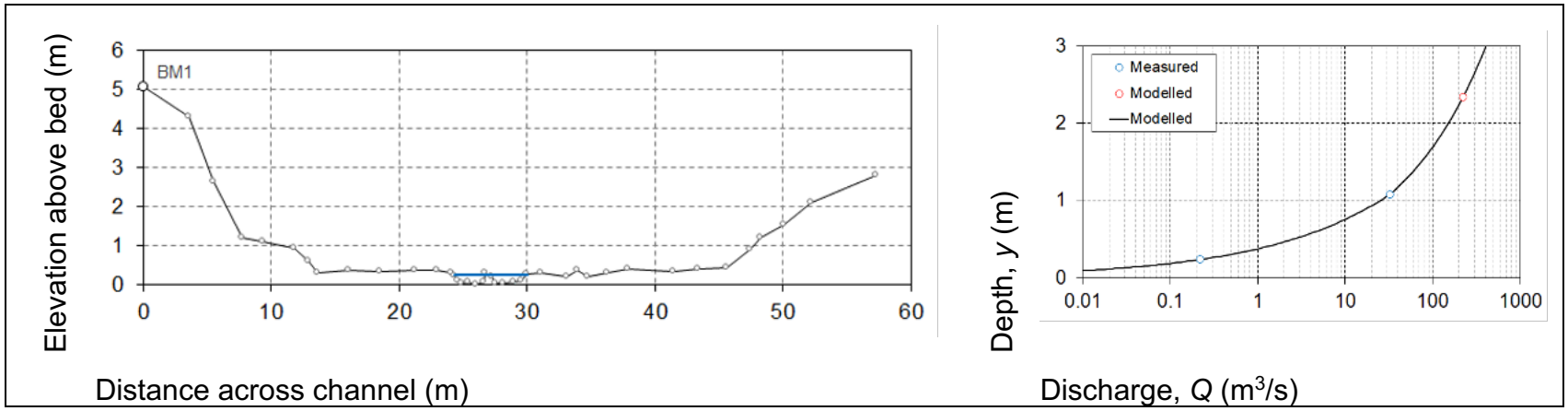


Figure 3.11: Cross-section and rating plots for the riffle cross-sections at 5_Mogalakwena2

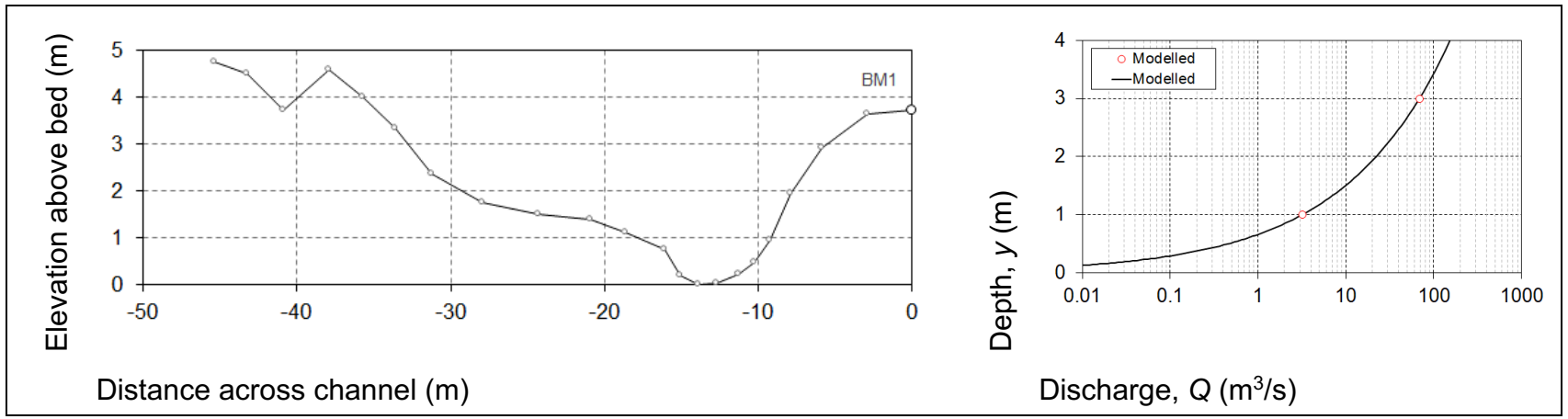


Figure 3.12: Cross-section and rating plots for the riffle cross-sections at 6_Kolope

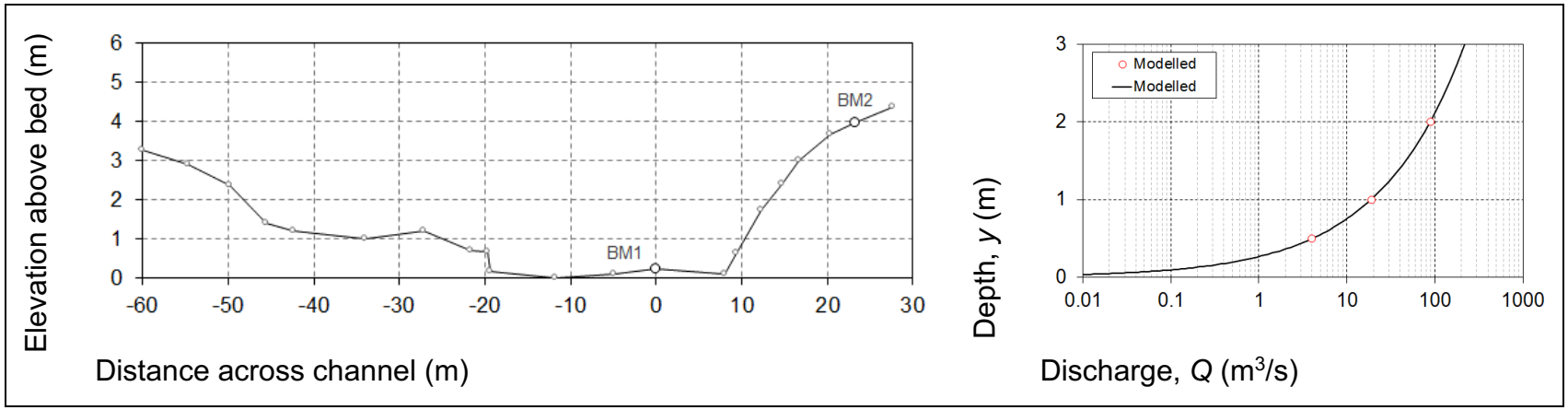


Figure 3.13: Cross-section and rating plots for the riffle cross-sections at 7_Sand

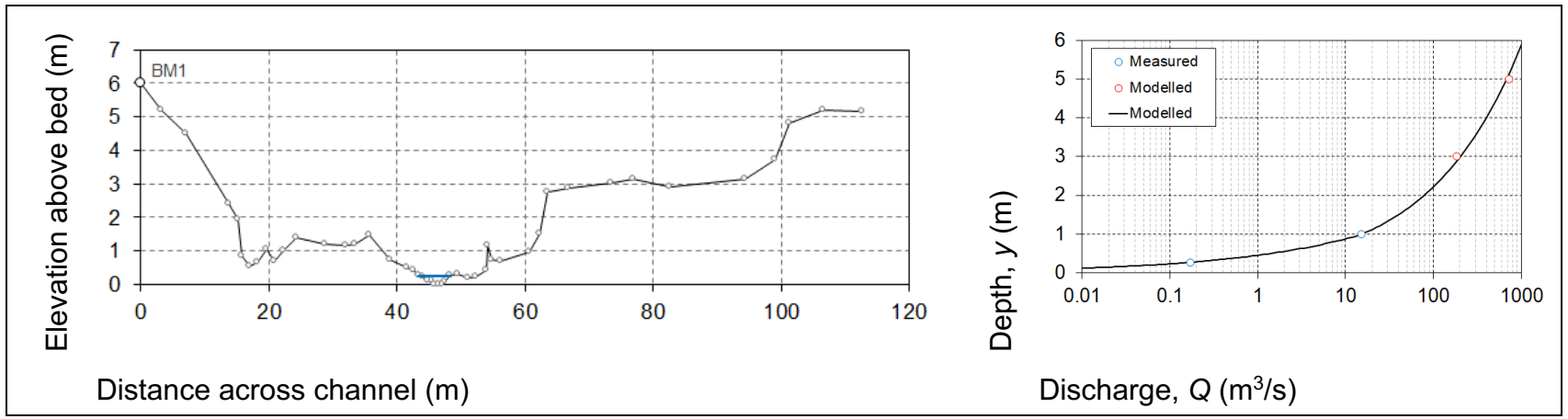


Figure 3.14: Cross-section and rating plots for the riffle cross-sections at 8_Nzhelele

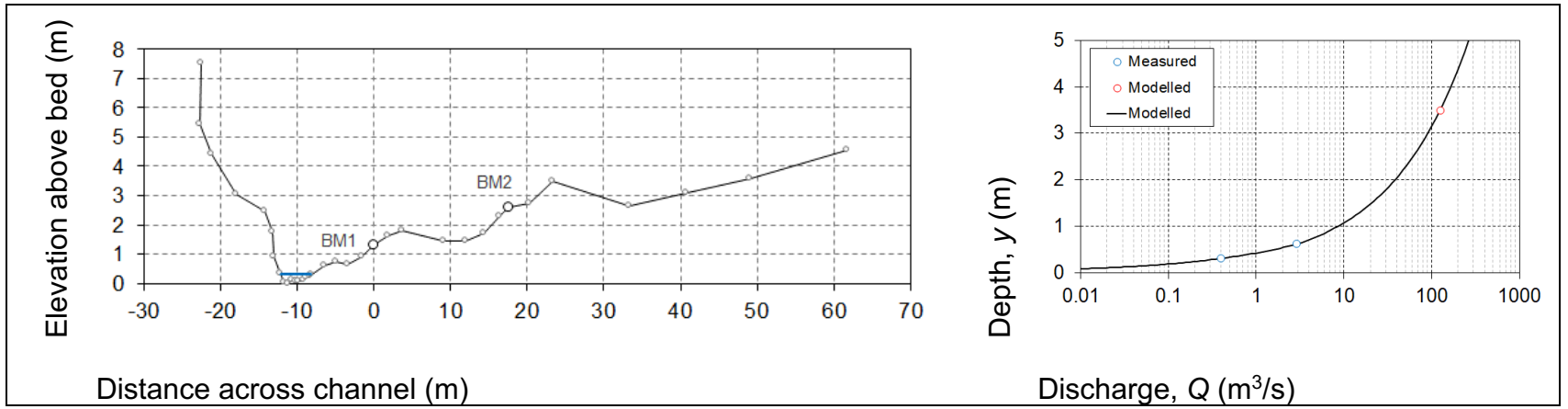


Figure 3.15: Cross-section and rating plots for the riffle cross-sections at 9_ Ṅwaneḍi

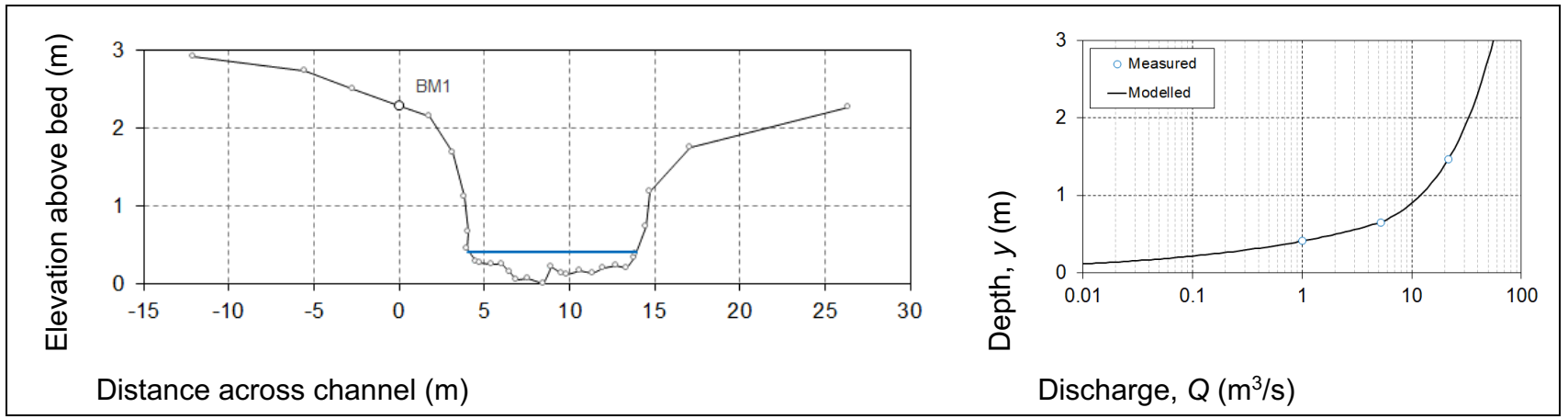


Figure 3.16: Cross-section and rating plots for the riffle cross-sections at 10_Latonyanda

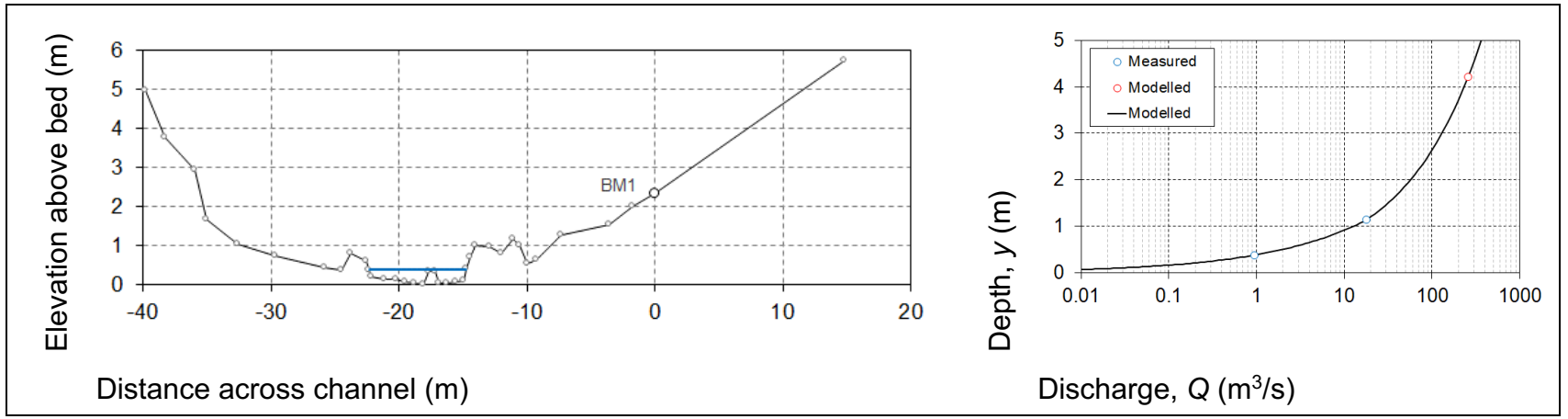


Figure 3.17: Cross-section and rating plots for the riffle cross-sections at 11_Mutshindudi

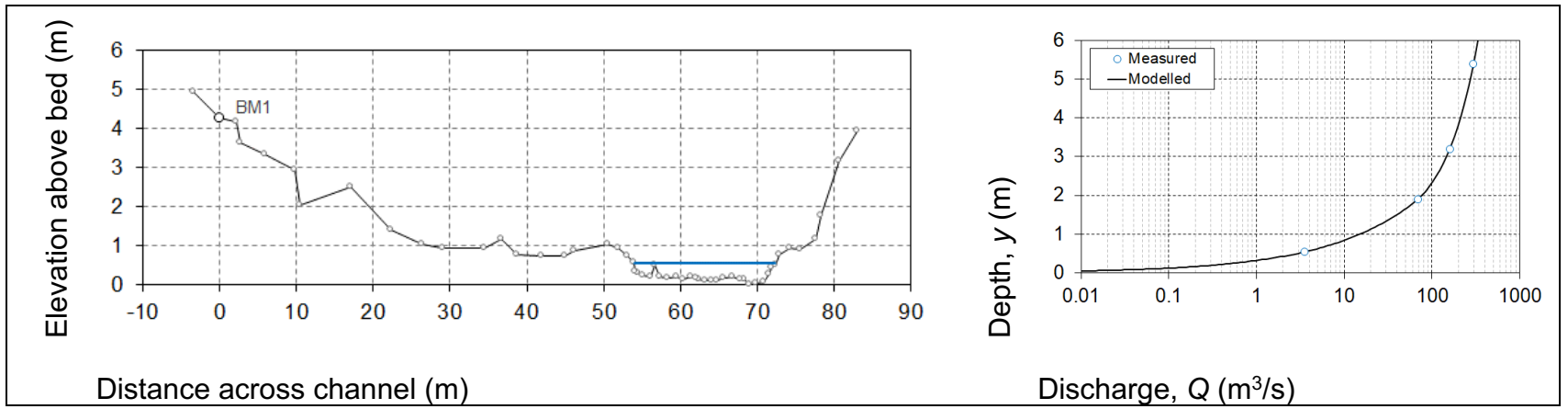


Figure 3.18: Cross-section and rating plots for the riffle cross-sections at 12_Luvuvhu

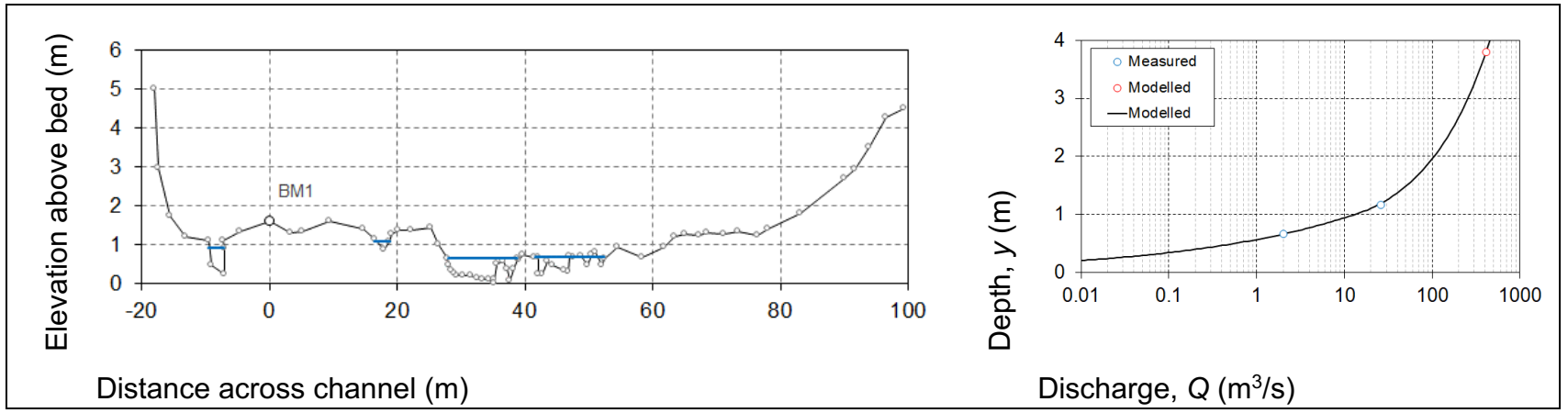


Figure 3.19: Cross-section and rating plots for the riffle cross-sections at 13_Mutale1

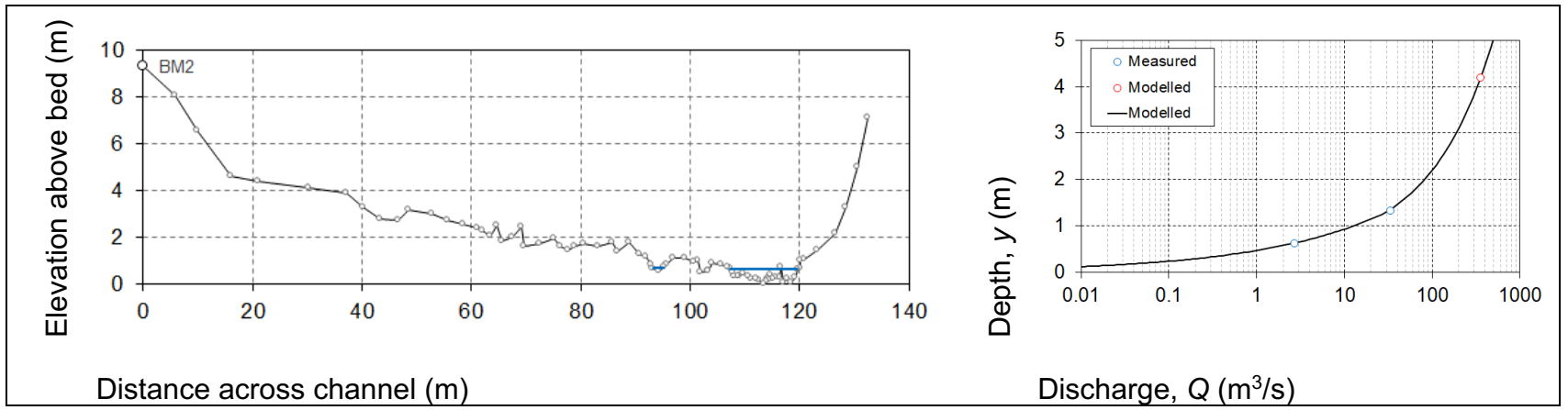


Figure 3.20: Cross-section and rating plots for the riffle cross-sections at 14_Mutale2

3.4 Results and input of hydraulic indicators to DRIFT-Limpopo DSS

The HABitat FLOw simulation model (HABFLO; Birkhead 2010) was used to synthesize text tables of ecologically-relevant hydraulic parameter values as a function of discharge for the cross-sections. The data are provided for all the EWR sites in **Table 3.3 to Table 3.17**. Relevant parameters from these tables were imported into DRIFT-Limpopo, which provide the hydraulic indicators at each EWR site.

Table 3.3: Ecologically relevant hydraulic paramaters at 1_Lephalala[3]

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.02	0	0	0.33	0.34	0.01	0.03	100	0	0	0	0	0
0.04	0.01	0	1.42	1.46	0.02	0.07	100	0	0	0	0	0
0.06	0.02	0.002	2.66	2.72	0.03	0.1	100	0	0	0	0	0
0.08	0.03	0.004	4.18	4.26	0.03	0.12	100	0	0	0	0	0
0.1	0.04	0.01	6.14	6.24	0.04	0.15	100	0	0	0	0	0
0.12	0.05	0.02	6.97	7.1	0.05	0.19	95	5	0	0	0	0
0.14	0.07	0.034	7.25	7.4	0.07	0.24	80	20	0	0	0	0
0.16	0.09	0.054	7.48	7.65	0.08	0.29	62	36	0	1	1	0
0.18	0.1	0.078	7.7	7.89	0.1	0.34	43	52	0	2	3	0
0.2	0.12	0.109	7.91	8.11	0.11	0.39	21	72	0	2	6	0
0.22	0.14	0.146	8.09	8.31	0.13	0.45	12	78	0	1	8	0
0.24	0.16	0.191	8.25	8.49	0.15	0.51	10	77	0	2	11	0
0.26	0.17	0.244	8.4	8.67	0.17	0.58	10	74	0	2	14	0
0.28	0.19	0.309	8.56	8.85	0.19	0.64	8	72	0	2	18	0
0.3	0.2	0.383	8.84	9.15	0.21	0.73	8	67	0	3	22	0
0.32	0.22	0.471	9.16	9.49	0.24	0.8	8	61	0	4	26	1
0.34	0.23	0.579	9.48	9.83	0.27	0.88	8	56	0	4	27	5
0.36	0.24	0.713	9.75	10.11	0.3	0.99	8	49	0	6	25	12
0.38	0.26	0.88	9.97	10.37	0.34	1.11	6	44	0	6	21	22
0.4	0.27	1.048	10.19	10.6	0.38	1.21	6	39	0	7	15	33
0.42	0.29	1.193	10.33	10.76	0.4	1.27	5	37	0	6	13	39
0.44	0.3	1.35	10.4	10.85	0.43	1.3	3	36	0	5	14	43
0.46	0.32	1.519	10.48	10.94	0.45	1.37	3	34	0	4	13	46
0.48	0.34	1.701	10.56	11.04	0.47	1.42	2	32	0	4	14	47
0.5	0.36	1.895	10.63	11.13	0.5	1.46	1	30	0	3	15	50
0.52	0.37	2.103	10.71	11.22	0.52	1.49	1	27	2	2	15	53
0.54	0.39	2.325	10.79	11.32	0.55	1.53	1	23	4	2	14	55
0.56	0.41	2.561	10.88	11.42	0.58	1.57	1	19	7	2	13	58
0.58	0.42	2.811	11.01	11.56	0.6	1.62	1	14	10	3	13	59
0.6	0.42	3.075	11.62	12.19	0.63	1.66	2	10	12	6	12	59
0.62	0.4	3.355	12.82	13.41	0.65	1.71	4	6	12	13	9	56
0.64	0.39	3.65	13.83	14.43	0.68	1.75	5	5	11	18	7	54
0.66	0.4	3.961	14.26	14.88	0.7	1.77	5	5	11	19	7	54
0.68	0.41	4.287	14.69	15.32	0.72	1.78	5	5	10	20	6	55
0.7	0.42	4.593	15.1	15.74	0.73	1.79	4	5	10	17	9	55
0.72	0.41	4.929	15.89	16.56	0.75	1.81	3	6	9	15	14	53
0.74	0.41	5.279	16.69	17.37	0.76	1.83	3	6	9	13	17	52
0.76	0.41	5.644	17.49	18.19	0.78	1.84	3	6	8	15	19	50
0.78	0.41	6.024	18.34	19.06	0.79	1.84	3	5	8	16	19	48
0.8	0.39	6.418	20.28	21.02	0.8	1.87	4	5	7	21	19	44
0.82	0.38	6.828	22.22	22.98	0.81	1.91	5	5	7	24	20	40
0.84	0.38	7.253	23.37	24.14	0.82	1.91	5	5	6	24	22	38

[3] Note, the number of decimal places for the various parameters does not imply accuracy (particularly with increasing flow), but is a function of the range of values for which tabulated results are required

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.86	0.38	7.694	24.42	25.21	0.82	1.89	4	5	6	21	25	38
0.88	0.35	8.15	28.19	28.99	0.83	1.92	5	5	6	27	24	33
0.9	0.34	8.622	30.59	31.4	0.82	1.93	5	5	5	29	23	33
0.92	0.34	9.111	32.58	33.41	0.82	1.93	5	6	5	28	23	33
0.94	0.35	9.615	33.93	34.77	0.82	1.94	5	7	5	24	26	34
0.96	0.36	10.136	34.18	35.01	0.81	1.91	4	7	5	19	30	35
0.98	0.38	10.674	34.42	35.26	0.81	1.91	3	8	5	16	32	36
1	0.38	11.228	36.08	36.92	0.81	1.89	3	8	5	15	33	37
1.02	0.38	11.8	38.2	39.06	0.81	1.87	3	9	5	14	35	35
1.04	0.38	12.388	39.97	40.83	0.81	1.88	3	9	4	15	34	36
1.06	0.4	12.994	40.3	41.16	0.8	1.88	3	9	4	13	35	36
1.08	0.42	13.617	40.62	41.49	0.8	1.87	2	10	4	10	35	39
1.1	0.43	14.258	40.95	41.82	0.8	1.85	1	10	5	7	35	41
1.12	0.45	14.916	41.28	42.15	0.8	1.83	1	10	5	6	32	46
1.14	0.47	15.593	41.6	42.48	0.8	1.86	1	10	5	6	30	49
1.16	0.48	16.288	41.93	42.81	0.8	1.87	1	10	5	5	28	51
1.18	0.5	17.001	42.26	43.14	0.81	1.86	1	10	5	4	26	54
1.2	0.52	17.732	42.58	43.47	0.81	1.82	0	9	6	3	23	59
1.22	0.53	18.482	42.91	43.81	0.81	1.84	0	9	6	2	21	61
1.24	0.55	19.251	43.24	44.14	0.81	1.86	1	9	6	3	17	64
1.26	0.56	20.039	43.56	44.47	0.82	1.87	1	9	6	3	14	67
1.28	0.58	20.845	43.89	44.8	0.82	1.85	0	8	7	2	12	71
1.3	0.59	21.671	44.22	45.13	0.82	1.85	0	8	7	2	10	73
1.32	0.61	22.517	44.77	45.69	0.83	1.85	1	7	8	3	9	73
1.34	0.62	23.381	45.55	46.47	0.83	1.86	1	6	8	4	9	73
1.36	0.63	24.266	46.34	47.26	0.84	1.89	1	5	8	5	8	72
1.38	0.64	25.17	47.12	48.05	0.84	1.9	1	5	9	6	6	73
1.4	0.65	26.094	47.9	48.83	0.84	1.88	1	4	9	5	7	73
1.42	0.65	27.039	48.68	49.62	0.85	1.92	1	4	9	6	6	73
1.44	0.66	28.003	49.47	50.4	0.85	1.94	1	4	9	7	6	73
1.46	0.67	28.988	50.23	51.17	0.86	1.94	1	3	9	7	7	72
1.48	0.68	29.994	50.98	51.93	0.86	1.94	1	3	9	7	8	71
1.5	0.69	31.02	51.74	52.69	0.86	1.94	1	3	10	7	9	71
1.52	0.7	32.067	52.5	53.46	0.87	1.95	1	3	10	7	9	71
1.54	0.71	33.135	53.25	54.21	0.87	1.93	1	3	10	6	9	71
1.56	0.72	34.224	53.89	54.86	0.88	1.91	1	3	10	5	11	70
1.58	0.74	35.335	54.53	55.51	0.88	1.95	1	3	10	6	11	70
1.6	0.75	36.466	55.17	56.16	0.88	1.96	1	3	10	6	11	70
1.62	0.76	37.619	55.81	56.81	0.89	1.96	1	3	10	5	11	71
1.64	0.77	38.794	56.46	57.45	0.89	1.96	1	3	10	5	12	70
1.66	0.78	39.991	57.1	58.1	0.9	1.99	1	3	10	5	12	70
1.68	0.79	41.21	57.74	58.75	0.9	1.98	1	3	10	5	11	71
1.7	0.8	42.45	58.38	59.4	0.9	1.97	1	3	10	4	11	72
1.72	0.81	43.713	59.03	60.05	0.91	1.96	1	3	10	4	11	72
1.74	0.83	44.998	59.67	60.69	0.91	2.01	1	3	9	4	11	72
1.76	0.84	46.306	60.31	61.34	0.92	2.03	1	3	9	4	11	72
1.78	0.85	47.636	60.95	61.99	0.92	2.01	1	3	9	4	10	74
1.8	0.85	48.988	62.33	63.38	0.93	2.02	1	3	9	5	9	74
1.82	0.84	50.364	64.82	65.87	0.93	2.05	1	3	8	7	10	71
1.84	0.82	51.763	67.3	68.36	0.93	2.03	1	3	8	9	9	70
1.86	0.82	53.184	69.52	70.58	0.94	2.06	1	3	8	11	9	68
1.88	0.82	54.629	71.47	72.54	0.94	2.03	1	3	8	11	10	68
1.9	0.81	56.097	73.42	74.49	0.94	2.05	2	3	8	12	9	66
1.92	0.81	57.589	75.37	76.45	0.94	2.04	2	3	8	12	9	66
1.94	0.81	59.104	77.32	78.4	0.94	2.05	2	3	8	12	11	65
1.96	0.81	60.643	79.27	80.36	0.94	2.04	1	3	8	11	13	64

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
1.98	0.81	62.206	81.22	82.31	0.94	2.05	1	3	7	11	15	62
2	0.82	63.793	82.37	83.47	0.94	2.03	1	3	8	9	16	63
2.02	0.83	65.404	83.1	84.21	0.94	2.02	1	3	8	8	16	63
2.04	0.85	67.039	83.83	84.94	0.95	2.06	1	3	7	8	18	63
2.06	0.86	68.699	84.56	85.68	0.95	2.07	1	3	7	7	18	63
2.08	0.87	70.382	85.29	86.41	0.95	2.06	1	3	8	6	18	64
2.1	0.88	72.091	86.02	87.15	0.95	2.06	1	4	8	4	18	66
2.12	0.9	73.824	86.74	87.88	0.95	2.08	1	4	8	4	17	67
2.14	0.91	75.582	87.47	88.62	0.95	2.09	0	4	8	4	16	69
2.16	0.92	77.365	88.27	89.42	0.95	2.09	0	4	8	4	15	70
2.18	0.93	79.173	89.1	90.25	0.95	2.08	0	4	8	3	14	72
2.2	0.94	81.006	89.94	91.09	0.96	2.1	0	4	8	3	12	72
2.22	0.95	82.864	90.77	91.92	0.96	2.09	0	4	8	4	11	74
2.24	0.97	84.748	91.6	92.75	0.96	2.08	0	4	8	3	10	75
2.26	0.98	86.657	92.43	93.59	0.96	2.07	0	4	8	3	9	76
2.28	0.99	88.592	93.26	94.42	0.96	2.1	1	3	8	4	8	76
2.3	1	90.552	94.09	95.25	0.96	2.08	0	3	8	3	7	78
2.32	1.01	92.539	94.92	96.08	0.97	2.09	0	3	8	3	7	78
2.34	1.02	94.551	95.75	96.92	0.97	2.11	1	3	8	4	7	77
2.36	1.03	96.589	96.58	97.75	0.97	2.11	1	3	9	4	7	77
2.38	1.04	98.654	97.42	98.58	0.97	2.09	0	3	9	3	7	78
2.4	1.05	100.745	98.25	99.42	0.97	2.12	1	2	9	4	7	78
2.42	1.07	102.862	99.08	100.25	0.97	2.13	0	2	9	4	7	78
2.44	1.08	105.006	99.91	101.08	0.98	2.11	0	2	9	3	7	78
2.46	1.09	107.177	100.74	101.91	0.98	2.16	0	2	9	4	7	77
2.48	1.1	109.374	101.57	102.75	0.98	2.17	0	2	9	4	7	77
2.5	1.11	111.598	102.4	103.58	0.98	2.15	0	2	9	3	7	78
2.52	1.12	113.849	103.22	104.4	0.98	2.18	0	2	9	4	7	78
2.54	1.13	116.127	104.04	105.22	0.99	2.18	0	2	9	4	7	78
2.56	1.14	118.432	104.85	106.04	0.99	2.16	0	2	9	3	7	79
2.58	1.15	120.765	105.67	106.86	0.99	2.19	0	2	9	4	7	78
2.6	1.17	123.125	106.49	107.68	0.99	2.19	0	2	9	4	7	78
2.62	1.18	125.512	107.31	108.49	0.99	2.17	0	2	9	3	7	79
2.64	1.19	127.928	108.12	109.31	1	2.2	0	2	9	3	7	78
2.66	1.2	130.37	108.94	110.13	1	2.21	0	2	9	3	7	78
2.68	1.21	132.841	109.76	110.95	1	2.18	0	2	9	2	7	79
2.7	1.22	135.34	110.57	111.77	1	2.21	0	2	9	3	7	79

SvS=Slow very Shallow; SS=Slow Shallow; SD=Slow Deep; FvS=Fast very Shallow; FS=Fast Shallow; FD=Fast Deep (for velocity and depth ranges refer to Birkhead 2010)

Table 3.4: Ecologically relevant hydraulic paramaters at 2_Rietfontein

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.02	0.01	0	0.38	0.39	0	0	100	0	0	0	0	0
0.04	0.02	0	0.77	0.78	0	0.01	100	0	0	0	0	0
0.06	0.03	0	1.15	1.16	0	0.01	100	0	0	0	0	0
0.08	0.04	0	1.43	1.45	0	0.01	100	0	0	0	0	0
0.1	0.05	0	1.72	1.75	0	0.02	99	1	0	0	0	0
0.12	0.06	0.001	2.02	2.06	0.01	0.02	81	19	0	0	0	0
0.14	0.07	0.001	2.31	2.36	0.01	0.02	67	33	0	0	0	0
0.16	0.08	0.002	2.67	2.73	0.01	0.03	57	43	0	0	0	0
0.18	0.08	0.002	3.38	3.45	0.01	0.03	58	42	0	0	0	0
0.2	0.09	0.003	4.08	4.16	0.01	0.03	57	43	0	0	0	0
0.22	0.09	0.004	4.73	4.82	0.01	0.03	58	42	0	0	0	0
0.24	0.1	0.006	5.32	5.41	0.01	0.04	56	44	0	0	0	0
0.26	0.11	0.008	5.9	6	0.01	0.04	55	45	0	0	0	0
0.28	0.12	0.011	6.48	6.59	0.01	0.05	47	53	0	0	0	0
0.3	0.13	0.015	7.07	7.18	0.02	0.06	42	58	0	0	0	0
0.32	0.14	0.02	7.65	7.77	0.02	0.07	38	62	0	0	0	0
0.34	0.15	0.026	8.22	8.36	0.02	0.08	35	65	0	0	0	0
0.36	0.16	0.036	8.63	8.77	0.03	0.09	31	69	0	0	0	0
0.38	0.18	0.049	8.93	9.08	0.03	0.11	26	74	0	0	0	0
0.4	0.19	0.069	9.12	9.26	0.04	0.14	21	79	0	0	0	0
0.42	0.21	0.098	9.3	9.45	0.05	0.18	17	83	0	0	0	0
0.44	0.22	0.145	9.48	9.64	0.07	0.23	13	86	0	0	0	0
0.46	0.24	0.231	9.66	9.82	0.1	0.33	10	86	0	0	2	1
0.48	0.25	0.435	9.85	10.01	0.17	0.52	7	79	0	1	8	5
0.5	0.27	1.4	10.03	10.2	0.52	1.06	2	20	0	8	39	31
0.52	0.28	1.554	10.21	10.38	0.53	1.07	2	19	1	7	35	37
0.54	0.3	1.718	10.39	10.57	0.55	1.12	2	17	1	7	31	41
0.56	0.31	1.892	10.63	10.81	0.57	1.15	2	16	2	6	30	44
0.58	0.33	2.078	10.89	11.07	0.59	1.19	2	14	3	8	24	49
0.6	0.34	2.274	11.14	11.33	0.6	1.23	2	13	3	8	22	52
0.62	0.35	2.481	11.4	11.59	0.62	1.27	2	12	3	8	18	56
0.64	0.36	2.699	11.65	11.84	0.64	1.31	2	11	3	9	16	59
0.66	0.37	2.929	11.91	12.1	0.66	1.33	1	11	4	8	16	61
0.68	0.39	3.171	12.16	12.36	0.68	1.36	1	10	4	8	15	62
0.7	0.4	3.426	12.42	12.62	0.69	1.4	1	9	5	7	15	63
0.72	0.41	3.692	12.67	12.88	0.71	1.44	1	7	5	8	15	63
0.74	0.42	3.971	12.93	13.14	0.73	1.48	1	7	6	8	16	63
0.76	0.43	4.263	13.21	13.42	0.75	1.51	1	6	6	9	14	64
0.78	0.44	4.568	13.5	13.71	0.76	1.55	1	5	6	8	15	64
0.8	0.45	4.886	13.78	14	0.78	1.58	1	5	6	8	15	65
0.82	0.46	5.218	14.07	14.29	0.8	1.63	1	4	6	9	15	64
0.84	0.47	5.563	14.36	14.58	0.82	1.65	1	4	6	9	15	65
0.86	0.48	5.922	14.65	14.87	0.83	1.7	1	3	6	9	15	64
0.88	0.5	6.296	14.94	15.17	0.85	1.73	1	3	6	9	15	65
0.9	0.51	6.683	15.23	15.46	0.87	1.75	1	3	6	8	15	66
0.92	0.52	7.086	15.5	15.74	0.89	1.8	1	3	6	9	15	66
0.94	0.53	7.503	15.76	16	0.9	1.81	1	3	6	7	17	67
0.96	0.54	7.935	16.03	16.27	0.92	1.85	1	3	6	7	16	67
0.98	0.55	8.382	16.29	16.53	0.94	1.91	1	3	6	7	16	67
1	0.56	8.845	16.56	16.81	0.95	1.94	1	3	6	7	15	68
1.02	0.57	9.323	16.84	17.09	0.97	1.95	1	3	6	6	16	69
1.04	0.58	9.817	17.13	17.38	0.99	1.99	1	3	5	6	16	70
1.06	0.59	10.327	17.41	17.66	1	2.02	1	3	5	6	15	70
1.08	0.6	10.853	17.69	17.95	1.02	2.06	1	3	5	6	15	71

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
1.1	0.61	11.396	17.97	18.23	1.03	2.1	1	3	5	7	14	70
1.12	0.62	11.956	18.26	18.52	1.05	2.14	1	2	5	7	14	71
1.14	0.63	12.532	18.54	18.8	1.07	2.17	1	2	5	7	14	71
1.16	0.65	13.125	18.78	19.05	1.08	2.2	1	2	5	6	14	72
1.18	0.66	13.735	18.99	19.26	1.1	2.23	1	2	5	6	14	72
1.2	0.67	14.363	19.19	19.47	1.12	2.28	0	2	5	6	14	73
1.22	0.68	15.009	19.4	19.68	1.13	2.29	0	2	5	4	14	74
1.24	0.7	15.672	19.61	19.89	1.15	2.33	0	2	5	5	13	75
1.26	0.71	16.353	19.81	20.1	1.16	2.37	0	2	5	5	13	75
1.28	0.72	17.053	20.02	20.31	1.18	2.4	0	2	5	5	13	75
1.3	0.73	17.77	20.23	20.52	1.2	2.41	0	2	5	3	13	77
1.32	0.75	18.507	20.43	20.73	1.21	2.47	0	2	5	4	12	77
1.34	0.76	19.262	20.64	20.95	1.23	2.5	0	2	5	4	12	78
1.36	0.77	20.036	20.88	21.18	1.25	2.5	0	2	5	3	12	79
1.38	0.76	20.829	21.66	21.97	1.26	2.53	0	2	4	6	10	77
1.4	0.76	21.642	22.44	22.76	1.28	2.6	1	1	4	9	10	75
1.42	0.76	22.474	22.85	23.17	1.29	2.64	1	1	4	10	10	74
1.44	0.78	23.325	23.01	23.33	1.31	2.67	1	1	4	10	9	76
1.46	0.79	24.197	23.17	23.5	1.32	2.67	0	1	4	8	9	78
1.48	0.81	25.088	23.33	23.66	1.34	2.71	0	1	4	7	10	77
1.5	0.82	26	23.49	23.82	1.35	2.74	0	1	4	4	13	77
1.52	0.83	26.932	23.64	23.99	1.37	2.76	0	1	4	2	15	78
1.54	0.85	27.885	23.8	24.15	1.38	2.82	0	1	4	3	15	77
1.56	0.86	28.858	23.96	24.31	1.4	2.83	0	1	4	2	14	79
1.58	0.88	29.853	24.12	24.48	1.41	2.85	0	1	4	2	13	79
1.6	0.89	30.868	24.28	24.64	1.43	2.87	0	1	4	2	13	80
1.62	0.91	31.905	24.44	24.81	1.44	2.94	0	1	4	3	12	80
1.64	0.92	32.963	24.59	24.97	1.46	2.96	0	1	4	3	12	81
1.66	0.93	34.043	24.75	25.13	1.47	2.99	0	1	4	2	11	81
1.68	0.95	35.145	24.91	25.3	1.49	3	0	1	4	2	10	83
1.7	0.96	36.269	25.07	25.46	1.5	3.07	0	1	4	2	10	83
1.72	0.98	37.414	25.23	25.62	1.52	3.09	0	1	4	2	9	84
1.74	0.99	38.583	25.39	25.79	1.54	3.12	0	1	4	2	8	85
1.76	1	39.773	25.55	25.96	1.55	3.12	0	1	4	2	7	87
1.78	1.01	40.986	25.79	26.2	1.57	3.19	0	1	4	3	6	86
1.8	1.02	42.223	26.03	26.45	1.58	3.19	0	1	4	2	6	87
1.82	1.03	43.482	26.27	26.69	1.6	3.24	0	1	3	3	6	86
1.84	1.05	44.764	26.52	26.93	1.62	3.27	0	1	3	4	6	86
1.86	1.06	46.07	26.76	27.18	1.63	3.29	0	1	4	3	6	86
1.88	1.07	47.399	27	27.42	1.65	3.33	0	1	4	3	6	86
1.9	1.08	48.752	27.24	27.67	1.66	3.38	0	1	3	4	6	86
1.92	1.09	50.128	27.48	27.91	1.68	3.37	0	1	4	3	7	86
1.94	1.1	51.529	27.72	28.16	1.69	3.44	0	1	3	4	7	85
1.96	1.11	52.954	27.96	28.4	1.71	3.44	0	1	4	3	7	86
1.98	1.12	54.403	28.2	28.65	1.72	3.49	0	1	3	4	8	84
2	1.13	55.877	28.44	28.89	1.74	3.53	0	1	3	4	8	84
2.02	1.14	57.375	28.68	29.13	1.76	3.53	0	1	3	3	8	85
2.04	1.15	58.898	28.92	29.38	1.77	3.57	0	1	3	3	8	86
2.06	1.16	60.446	29.16	29.62	1.79	3.65	0	1	3	3	8	85
2.08	1.17	62.02	29.39	29.86	1.8	3.64	0	1	3	3	8	86
2.1	1.18	63.618	29.6	30.07	1.82	3.66	0	1	3	3	8	86
2.12	1.19	65.242	29.8	30.27	1.83	3.67	0	1	3	3	8	85
2.14	1.21	66.892	30	30.48	1.85	3.73	0	1	3	3	8	85
2.16	1.22	68.567	30.2	30.69	1.86	3.79	0	1	3	3	8	85
2.18	1.23	70.269	30.4	30.9	1.88	3.8	0	1	3	3	7	86
2.2	1.23	71.996	30.8	31.31	1.89	3.85	0	1	3	4	7	85

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
2.22	1.23	73.75	31.37	31.88	1.91	3.85	0	1	3	3	7	85
2.24	1.23	75.53	31.94	32.45	1.92	3.91	0	1	3	4	8	84
2.26	1.23	77.337	32.51	33.02	1.94	3.9	0	1	3	4	8	84
2.28	1.23	79.17	33.07	33.6	1.95	3.94	0	1	3	5	8	83
2.3	1.23	81.031	33.64	34.17	1.96	3.98	0	1	3	6	9	81
2.32	1.23	82.918	34.21	34.74	1.98	4.02	0	1	3	7	9	80
2.34	1.23	84.833	34.78	35.31	1.99	4	0	1	3	7	9	80
2.36	1.23	86.775	35.26	35.81	2	4.03	0	1	3	7	9	80
2.38	1.24	88.744	35.52	36.07	2.02	4.07	0	1	3	6	10	81
2.4	1.25	90.741	35.77	36.33	2.03	4.12	0	1	3	6	10	80
2.42	1.26	92.766	36.03	36.59	2.04	4.12	0	1	3	5	10	81
2.44	1.27	94.819	36.28	36.85	2.05	4.15	0	1	3	5	10	81
2.46	1.28	96.9	36.54	37.11	2.07	4.21	0	1	3	5	11	81
2.48	1.29	99.009	36.79	37.37	2.08	4.24	0	1	3	4	11	81
2.5	1.31	101.147	37.05	37.63	2.09	4.2	0	1	3	3	11	83

SvS=Slow very Shallow; SS=Slow Shallow; SD=Slow Deep; FvS=Fast very Shallow; FS=Fast Shallow; FD=Fast Deep (for velocity and depth ranges refer to Birkhead 2010)

Table 3.5: Ecologically relevant hydraulic paramaters at 2_Rietfontein

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.02	0.01	0	0.72	0.72	0	0	100	0	0	0	0	0
0.04	0.02	0	1.16	1.17	0	0.01	100	0	0	0	0	0
0.06	0.04	0	1.34	1.35	0	0.02	100	0	0	0	0	0
0.08	0.05	0.001	1.51	1.53	0.01	0.03	100	0	0	0	0	0
0.1	0.07	0.001	1.69	1.71	0.01	0.05	98	2	0	0	0	0
0.12	0.07	0.003	1.97	2	0.02	0.07	65	35	0	0	0	0
0.14	0.07	0.005	2.94	2.97	0.03	0.1	61	39	0	0	0	0
0.16	0.08	0.009	3.16	3.2	0.03	0.12	58	42	0	0	0	0
0.18	0.1	0.014	3.37	3.42	0.04	0.15	54	46	0	0	0	0
0.2	0.1	0.02	3.78	3.83	0.05	0.19	55	45	0	0	0	0
0.22	0.11	0.029	4.24	4.3	0.06	0.22	53	47	0	0	0	0
0.24	0.13	0.041	4.39	4.46	0.07	0.26	34	65	0	0	1	0
0.26	0.14	0.055	4.55	4.61	0.08	0.3	28	69	0	1	2	0
0.28	0.16	0.073	4.65	4.73	0.1	0.35	26	69	0	1	4	0
0.3	0.18	0.095	4.74	4.82	0.11	0.4	20	72	0	2	6	0
0.32	0.19	0.121	4.82	4.92	0.13	0.46	11	79	0	1	8	2
0.34	0.21	0.152	4.91	5.01	0.15	0.52	10	77	0	1	9	3
0.36	0.23	0.189	4.99	5.11	0.17	0.59	8	76	0	2	11	4
0.38	0.24	0.232	5.07	5.19	0.19	0.65	6	74	0	1	13	6
0.4	0.26	0.282	5.14	5.28	0.21	0.72	5	70	0	2	15	8
0.42	0.28	0.34	5.21	5.36	0.24	0.8	5	64	0	2	15	13
0.44	0.29	0.405	5.29	5.45	0.26	0.87	5	59	0	3	14	19
0.46	0.31	0.48	5.36	5.53	0.29	0.96	4	54	0	3	14	25
0.48	0.32	0.564	5.44	5.62	0.32	1.04	4	49	0	3	14	29
0.5	0.34	0.658	5.51	5.7	0.35	1.12	3	43	1	4	13	35
0.52	0.35	0.764	5.58	5.78	0.39	1.19	2	36	5	3	10	43
0.54	0.37	0.882	5.65	5.86	0.42	1.28	2	29	7	4	10	47
0.56	0.38	1.012	5.72	5.94	0.46	1.37	2	25	8	4	10	51
0.58	0.4	1.156	5.83	6.06	0.5	1.46	2	22	8	5	9	55
0.6	0.41	1.315	5.95	6.19	0.54	1.52	2	19	8	5	9	57
0.62	0.42	1.467	6.07	6.31	0.57	1.59	2	16	9	6	9	59
0.64	0.43	1.612	6.19	6.44	0.6	1.61	2	13	10	5	9	61

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.66	0.44	1.763	6.3	6.56	0.63	1.64	2	10	11	7	8	61
0.68	0.46	1.921	6.42	6.69	0.66	1.69	2	8	12	7	9	62
0.7	0.47	2.086	6.54	6.81	0.68	1.71	2	7	12	7	10	62
0.72	0.48	2.256	6.66	6.94	0.71	1.74	2	6	12	7	10	63
0.74	0.49	2.433	6.72	7.02	0.73	1.78	1	5	12	7	11	64
0.76	0.51	2.617	6.79	7.1	0.76	1.8	1	5	12	6	11	65
0.78	0.52	2.807	6.87	7.2	0.78	1.81	1	4	11	5	12	66
0.8	0.54	3.003	6.96	7.31	0.8	1.82	1	4	11	5	12	67
0.82	0.55	3.206	7.05	7.41	0.83	1.89	1	4	10	5	12	67
0.84	0.56	3.415	7.13	7.51	0.85	1.92	1	4	10	5	13	68
0.86	0.58	3.63	7.22	7.61	0.87	1.92	1	3	10	5	13	69
0.88	0.59	3.851	7.3	7.71	0.89	1.97	1	3	9	4	12	71
0.9	0.6	4.079	7.39	7.82	0.92	2.02	1	3	9	5	12	70
0.92	0.62	4.313	7.47	7.92	0.94	2.04	1	3	8	5	11	72
0.94	0.63	4.553	7.56	8.02	0.96	2.05	1	3	8	4	11	74
0.96	0.64	4.799	7.65	8.13	0.98	2.09	1	3	8	5	11	74
0.98	0.65	5.052	7.74	8.23	1	2.1	0	3	7	4	10	75
1	0.67	5.311	7.83	8.34	1.02	2.14	0	2	7	4	11	75
1.02	0.68	5.576	7.92	8.45	1.04	2.19	1	2	7	5	10	76
1.04	0.69	5.847	8.01	8.56	1.06	2.2	1	2	6	5	10	76
1.06	0.7	6.124	8.11	8.67	1.08	2.19	0	2	6	4	10	77
1.08	0.71	6.408	8.2	8.78	1.09	2.22	0	2	6	4	10	77
1.1	0.73	6.697	8.29	8.89	1.11	2.29	0	2	6	5	10	77
1.12	0.74	6.993	8.38	8.99	1.13	2.3	0	2	6	4	10	78
1.14	0.75	7.295	8.47	9.1	1.15	2.31	0	2	6	4	10	79
1.16	0.76	7.602	8.57	9.21	1.17	2.37	0	2	6	5	10	78
1.18	0.77	7.916	8.66	9.32	1.18	2.41	0	2	5	5	10	78
1.2	0.79	8.236	8.75	9.43	1.2	2.41	0	1	5	4	10	79
1.22	0.8	8.562	8.84	9.54	1.22	2.44	0	1	5	4	10	80
1.24	0.81	8.894	8.93	9.64	1.23	2.5	0	1	5	4	9	79
1.26	0.82	9.232	9.03	9.75	1.25	2.53	0	1	5	4	10	79
1.28	0.83	9.577	9.19	9.93	1.26	2.56	0	1	5	5	9	79
1.3	0.83	9.927	9.38	10.12	1.28	2.59	0	1	5	6	9	79
1.32	0.83	10.283	9.57	10.31	1.29	2.61	0	1	5	6	9	79
1.34	0.84	10.645	9.75	10.5	1.31	2.65	1	1	4	8	9	77
1.36	0.84	11.013	9.94	10.69	1.32	2.66	0	1	4	7	9	78
1.38	0.84	11.387	10.13	10.88	1.33	2.69	0	1	4	8	10	76
1.4	0.85	11.767	10.32	11.07	1.34	2.71	0	1	4	7	11	76
1.42	0.85	12.153	10.5	11.26	1.36	2.74	0	1	4	7	12	76
1.44	0.86	12.545	10.69	11.46	1.37	2.8	0	1	4	8	12	75
1.46	0.86	12.943	10.88	11.65	1.38	2.79	0	1	4	7	12	75
1.48	0.87	13.347	11.06	11.84	1.39	2.84	0	1	4	8	13	74
1.5	0.87	13.757	11.25	12.03	1.4	2.86	0	1	4	7	13	74
1.52	0.88	14.173	11.42	12.2	1.41	2.88	0	1	4	7	14	73
1.54	0.87	14.594	11.79	12.58	1.42	2.87	0	1	4	8	13	73
1.56	0.86	15.022	12.29	13.08	1.43	2.9	1	1	3	11	14	70
1.58	0.84	15.455	12.79	13.58	1.43	2.88	1	1	3	11	16	68
1.6	0.83	15.894	13.29	14.09	1.44	2.93	1	1	3	14	14	67
1.62	0.82	16.34	13.79	14.59	1.44	2.91	1	1	3	15	14	66
1.64	0.81	16.791	14.29	15.09	1.45	2.93	1	1	3	16	14	65
1.66	0.81	17.248	14.76	15.57	1.45	2.95	1	1	3	16	15	64
1.68	0.81	17.71	15.09	15.9	1.45	2.93	1	1	3	14	17	65
1.7	0.81	18.179	15.43	16.24	1.46	2.93	1	2	3	13	18	64
1.72	0.81	18.654	15.76	16.58	1.46	2.97	1	2	3	12	20	63
1.74	0.82	19.134	16.1	16.92	1.46	2.96	1	2	3	11	20	64
1.76	0.82	19.62	16.43	17.26	1.46	2.97	1	2	3	10	22	63

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
1.78	0.82	20.112	16.76	17.59	1.46	2.94	0	2	3	9	22	64
1.8	0.83	20.61	17.1	17.93	1.46	2.97	1	2	3	9	22	64
1.82	0.83	21.114	17.43	18.27	1.46	2.95	0	2	3	9	21	65
1.84	0.83	21.623	17.77	18.61	1.46	2.98	0	2	3	9	21	65
1.86	0.84	22.138	18.1	18.95	1.46	2.98	0	2	3	9	20	66
1.88	0.84	22.659	18.44	19.29	1.46	2.97	0	2	3	9	19	67
1.9	0.85	23.186	18.77	19.62	1.46	2.94	0	2	3	8	18	68
1.92	0.85	23.719	19.12	19.97	1.46	2.95	0	2	3	8	18	69
1.94	0.86	24.257	19.47	20.33	1.45	2.97	0	2	3	9	17	69
1.96	0.86	24.801	19.82	20.68	1.45	2.94	0	2	3	8	16	71
1.98	0.87	25.351	20.17	21.04	1.45	2.96	0	2	3	9	16	71
2	0.87	25.907	20.52	21.39	1.45	2.93	0	2	3	8	15	72
2.02	0.85	26.468	21.55	22.42	1.45	2.92	1	2	3	9	16	69
2.04	0.81	27.036	23.24	24.12	1.44	2.92	1	2	3	13	16	65
2.06	0.77	27.609	24.94	25.82	1.44	2.88	1	2	3	15	17	63
2.08	0.74	28.187	26.64	27.52	1.43	2.88	1	2	3	18	17	59
2.1	0.72	28.772	27.99	28.88	1.42	2.84	1	2	3	20	17	58
2.12	0.73	29.362	28.53	29.42	1.41	2.85	1	2	3	19	17	58
2.14	0.74	29.958	29.07	29.96	1.4	2.83	1	2	3	19	17	58
2.16	0.74	30.559	29.61	30.5	1.39	2.81	1	2	3	18	18	59
2.18	0.75	31.167	30.15	31.05	1.38	2.82	1	2	3	16	20	58
2.2	0.76	31.78	30.69	31.59	1.37	2.8	1	2	3	13	23	58

SvS=Slow very Shallow; SS=Slow Shallow; SD=Slow Deep; FvS=Fast very Shallow; FS=Fast Shallow; FD=Fast Deep (for velocity and depth ranges refer to Birkhead 2010)

Table 3.6: Ecologically relevant hydraulic indicators at 3_Olifantspruit

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.02	0.01	0	0.72	0.72	0	0	100	0	0	0	0	0
0.04	0.02	0	1.16	1.17	0	0.01	100	0	0	0	0	0
0.06	0.04	0	1.34	1.35	0	0.02	100	0	0	0	0	0
0.08	0.05	0.001	1.51	1.53	0.01	0.03	100	0	0	0	0	0
0.1	0.07	0.001	1.69	1.71	0.01	0.05	98	2	0	0	0	0
0.12	0.07	0.003	1.97	2	0.02	0.07	65	35	0	0	0	0
0.14	0.07	0.005	2.94	2.97	0.03	0.1	61	39	0	0	0	0
0.16	0.08	0.009	3.16	3.2	0.03	0.12	58	42	0	0	0	0
0.18	0.1	0.014	3.37	3.42	0.04	0.15	54	46	0	0	0	0
0.2	0.1	0.02	3.78	3.83	0.05	0.19	55	45	0	0	0	0
0.22	0.11	0.029	4.24	4.3	0.06	0.22	53	47	0	0	0	0
0.24	0.13	0.041	4.39	4.46	0.07	0.26	34	65	0	0	1	0
0.26	0.14	0.055	4.55	4.61	0.08	0.3	28	69	0	1	2	0
0.28	0.16	0.073	4.65	4.73	0.1	0.35	26	69	0	1	4	0
0.3	0.18	0.095	4.74	4.82	0.11	0.4	20	72	0	2	6	0
0.32	0.19	0.121	4.82	4.92	0.13	0.46	11	79	0	1	8	2
0.34	0.21	0.152	4.91	5.01	0.15	0.52	10	77	0	1	9	3
0.36	0.23	0.189	4.99	5.11	0.17	0.59	8	76	0	2	11	4
0.38	0.24	0.232	5.07	5.19	0.19	0.65	6	74	0	1	13	6
0.4	0.26	0.282	5.14	5.28	0.21	0.72	5	70	0	2	15	8
0.42	0.28	0.34	5.21	5.36	0.24	0.8	5	64	0	2	15	13
0.44	0.29	0.405	5.29	5.45	0.26	0.87	5	59	0	3	14	19
0.46	0.31	0.48	5.36	5.53	0.29	0.96	4	54	0	3	14	25
0.48	0.32	0.564	5.44	5.62	0.32	1.04	4	49	0	3	14	29
0.5	0.34	0.658	5.51	5.7	0.35	1.12	3	43	1	4	13	35

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.52	0.35	0.764	5.58	5.78	0.39	1.19	2	36	5	3	10	43
0.54	0.37	0.882	5.65	5.86	0.42	1.28	2	29	7	4	10	47
0.56	0.38	1.012	5.72	5.94	0.46	1.37	2	25	8	4	10	51
0.58	0.4	1.156	5.83	6.06	0.5	1.46	2	22	8	5	9	55
0.6	0.41	1.315	5.95	6.19	0.54	1.52	2	19	8	5	9	57
0.62	0.42	1.467	6.07	6.31	0.57	1.59	2	16	9	6	9	59
0.64	0.43	1.612	6.19	6.44	0.6	1.61	2	13	10	5	9	61
0.66	0.44	1.763	6.3	6.56	0.63	1.64	2	10	11	7	8	61
0.68	0.46	1.921	6.42	6.69	0.66	1.69	2	8	12	7	9	62
0.7	0.47	2.086	6.54	6.81	0.68	1.71	2	7	12	7	10	62
0.72	0.48	2.256	6.66	6.94	0.71	1.74	2	6	12	7	10	63
0.74	0.49	2.433	6.72	7.02	0.73	1.78	1	5	12	7	11	64
0.76	0.51	2.617	6.79	7.1	0.76	1.8	1	5	12	6	11	65
0.78	0.52	2.807	6.87	7.2	0.78	1.81	1	4	11	5	12	66
0.8	0.54	3.003	6.96	7.31	0.8	1.82	1	4	11	5	12	67
0.82	0.55	3.206	7.05	7.41	0.83	1.89	1	4	10	5	12	67
0.84	0.56	3.415	7.13	7.51	0.85	1.92	1	4	10	5	13	68
0.86	0.58	3.63	7.22	7.61	0.87	1.92	1	3	10	5	13	69
0.88	0.59	3.851	7.3	7.71	0.89	1.97	1	3	9	4	12	71
0.9	0.6	4.079	7.39	7.82	0.92	2.02	1	3	9	5	12	70
0.92	0.62	4.313	7.47	7.92	0.94	2.04	1	3	8	5	11	72
0.94	0.63	4.553	7.56	8.02	0.96	2.05	1	3	8	4	11	74
0.96	0.64	4.799	7.65	8.13	0.98	2.09	1	3	8	5	11	74
0.98	0.65	5.052	7.74	8.23	1	2.1	0	3	7	4	10	75
1	0.67	5.311	7.83	8.34	1.02	2.14	0	2	7	4	11	75
1.02	0.68	5.576	7.92	8.45	1.04	2.19	1	2	7	5	10	76
1.04	0.69	5.847	8.01	8.56	1.06	2.2	1	2	6	5	10	76
1.06	0.7	6.124	8.11	8.67	1.08	2.19	0	2	6	4	10	77
1.08	0.71	6.408	8.2	8.78	1.09	2.22	0	2	6	4	10	77
1.1	0.73	6.697	8.29	8.89	1.11	2.29	0	2	6	5	10	77
1.12	0.74	6.993	8.38	8.99	1.13	2.3	0	2	6	4	10	78
1.14	0.75	7.295	8.47	9.1	1.15	2.31	0	2	6	4	10	79
1.16	0.76	7.602	8.57	9.21	1.17	2.37	0	2	6	5	10	78
1.18	0.77	7.916	8.66	9.32	1.18	2.41	0	2	5	5	10	78
1.2	0.79	8.236	8.75	9.43	1.2	2.41	0	1	5	4	10	79
1.22	0.8	8.562	8.84	9.54	1.22	2.44	0	1	5	4	10	80
1.24	0.81	8.894	8.93	9.64	1.23	2.5	0	1	5	4	9	79
1.26	0.82	9.232	9.03	9.75	1.25	2.53	0	1	5	4	10	79
1.28	0.83	9.577	9.19	9.93	1.26	2.56	0	1	5	5	9	79
1.3	0.83	9.927	9.38	10.12	1.28	2.59	0	1	5	6	9	79
1.32	0.83	10.283	9.57	10.31	1.29	2.61	0	1	5	6	9	79
1.34	0.84	10.645	9.75	10.5	1.31	2.65	1	1	4	8	9	77
1.36	0.84	11.013	9.94	10.69	1.32	2.66	0	1	4	7	9	78
1.38	0.84	11.387	10.13	10.88	1.33	2.69	0	1	4	8	10	76
1.4	0.85	11.767	10.32	11.07	1.34	2.71	0	1	4	7	11	76
1.42	0.85	12.153	10.5	11.26	1.36	2.74	0	1	4	7	12	76
1.44	0.86	12.545	10.69	11.46	1.37	2.8	0	1	4	8	12	75
1.46	0.86	12.943	10.88	11.65	1.38	2.79	0	1	4	7	12	75
1.48	0.87	13.347	11.06	11.84	1.39	2.84	0	1	4	8	13	74
1.5	0.87	13.757	11.25	12.03	1.4	2.86	0	1	4	7	13	74
1.52	0.88	14.173	11.42	12.2	1.41	2.88	0	1	4	7	14	73
1.54	0.87	14.594	11.79	12.58	1.42	2.87	0	1	4	8	13	73
1.56	0.86	15.022	12.29	13.08	1.43	2.9	1	1	3	11	14	70
1.58	0.84	15.455	12.79	13.58	1.43	2.88	1	1	3	11	16	68
1.6	0.83	15.894	13.29	14.09	1.44	2.93	1	1	3	14	14	67
1.62	0.82	16.34	13.79	14.59	1.44	2.91	1	1	3	15	14	66

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
1.64	0.81	16.791	14.29	15.09	1.45	2.93	1	1	3	16	14	65
1.66	0.81	17.248	14.76	15.57	1.45	2.95	1	1	3	16	15	64
1.68	0.81	17.71	15.09	15.9	1.45	2.93	1	1	3	14	17	65
1.7	0.81	18.179	15.43	16.24	1.46	2.93	1	2	3	13	18	64
1.72	0.81	18.654	15.76	16.58	1.46	2.97	1	2	3	12	20	63
1.74	0.82	19.134	16.1	16.92	1.46	2.96	1	2	3	11	20	64
1.76	0.82	19.62	16.43	17.26	1.46	2.97	1	2	3	10	22	63
1.78	0.82	20.112	16.76	17.59	1.46	2.94	0	2	3	9	22	64
1.8	0.83	20.61	17.1	17.93	1.46	2.97	1	2	3	9	22	64
1.82	0.83	21.114	17.43	18.27	1.46	2.95	0	2	3	9	21	65
1.84	0.83	21.623	17.77	18.61	1.46	2.98	0	2	3	9	21	65
1.86	0.84	22.138	18.1	18.95	1.46	2.98	0	2	3	9	20	66
1.88	0.84	22.659	18.44	19.29	1.46	2.97	0	2	3	9	19	67
1.9	0.85	23.186	18.77	19.62	1.46	2.94	0	2	3	8	18	68
1.92	0.85	23.719	19.12	19.97	1.46	2.95	0	2	3	8	18	69
1.94	0.86	24.257	19.47	20.33	1.45	2.97	0	2	3	9	17	69
1.96	0.86	24.801	19.82	20.68	1.45	2.94	0	2	3	8	16	71
1.98	0.87	25.351	20.17	21.04	1.45	2.96	0	2	3	9	16	71
2	0.87	25.907	20.52	21.39	1.45	2.93	0	2	3	8	15	72
2.02	0.85	26.468	21.55	22.42	1.45	2.92	1	2	3	9	16	69
2.04	0.81	27.036	23.24	24.12	1.44	2.92	1	2	3	13	16	65
2.06	0.77	27.609	24.94	25.82	1.44	2.88	1	2	3	15	17	63
2.08	0.74	28.187	26.64	27.52	1.43	2.88	1	2	3	18	17	59
2.1	0.72	28.772	27.99	28.88	1.42	2.84	1	2	3	20	17	58
2.12	0.73	29.362	28.53	29.42	1.41	2.85	1	2	3	19	17	58
2.14	0.74	29.958	29.07	29.96	1.4	2.83	1	2	3	19	17	58
2.16	0.74	30.559	29.61	30.5	1.39	2.81	1	2	3	18	18	59
2.18	0.75	31.167	30.15	31.05	1.38	2.82	1	2	3	16	20	58
2.2	0.76	31.78	30.69	31.59	1.37	2.8	1	2	3	13	23	58

SvS=Slow very Shallow; SS=Slow Shallow; SD=Slow Deep; FvS=Fast very Shallow; FS=Fast Shallow; FD=Fast Deep (for velocity and depth ranges refer to Birkhead 2010)

Table 3.7: Ecologically relevant hydraulic indicators at 4_Mogalakwena

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.02	0	0	0.67	0.67	0.01	0.04	100	0	0	0	0	0
0.04	0.02	0.001	1.26	1.27	0.03	0.1	100	0	0	0	0	0
0.06	0.03	0.002	1.86	1.88	0.04	0.15	100	0	0	0	0	0
0.08	0.04	0.005	2.55	2.57	0.05	0.18	100	0	0	0	0	0
0.1	0.05	0.01	3.03	3.06	0.07	0.23	99	0	0	0	0	0
0.12	0.07	0.018	3.19	3.23	0.08	0.29	81	17	0	2	0	0
0.14	0.09	0.029	3.29	3.33	0.1	0.36	58	36	0	3	2	0
0.16	0.1	0.043	3.38	3.44	0.12	0.42	40	51	0	4	5	0
0.18	0.12	0.061	3.48	3.54	0.15	0.49	23	66	0	3	8	0
0.2	0.14	0.083	3.58	3.65	0.17	0.55	10	76	0	2	13	0
0.22	0.15	0.11	3.67	3.75	0.2	0.63	6	74	0	2	18	0
0.24	0.17	0.143	3.77	3.86	0.23	0.7	4	71	0	1	23	0
0.26	0.19	0.178	3.69	4.06	0.25	0.79	3	65	0	1	31	0
0.28	0.22	0.217	3.61	4.33	0.28	0.89	3	57	0	2	39	0
0.3	0.22	0.261	3.82	4.55	0.31	0.96	5	49	0	4	41	0
0.32	0.23	0.311	4.03	4.77	0.33	1.03	7	42	0	7	38	6
0.34	0.24	0.366	4.24	4.99	0.36	1.08	8	37	0	10	29	17
0.36	0.25	0.426	4.46	5.21	0.39	1.13	8	33	0	12	22	25
0.38	0.26	0.493	4.67	5.42	0.41	1.17	8	30	0	14	15	34
0.4	0.26	0.566	4.88	5.64	0.44	1.21	7	28	0	14	11	40
0.42	0.27	0.645	5.09	5.86	0.46	1.27	7	25	0	14	11	42
0.44	0.28	0.731	5.28	6.06	0.49	1.3	6	24	0	14	12	44
0.46	0.3	0.824	5.39	6.18	0.51	1.33	5	23	0	13	15	45
0.48	0.31	0.924	5.52	6.31	0.54	1.36	4	22	0	12	17	46
0.5	0.32	1.031	5.69	6.49	0.57	1.37	3	21	1	10	20	46
0.52	0.33	1.146	5.86	6.66	0.59	1.41	3	17	3	10	21	46
0.54	0.34	1.268	6.02	6.84	0.62	1.43	3	14	5	10	24	45
0.56	0.35	1.398	6.19	7.01	0.64	1.47	2	12	6	10	24	46
0.58	0.36	1.536	6.36	7.18	0.67	1.5	2	9	7	10	24	47
0.6	0.37	1.683	6.53	7.36	0.69	1.53	2	8	8	11	24	48
0.62	0.38	1.838	6.7	7.53	0.72	1.56	2	7	8	10	23	50
0.64	0.39	2.002	6.87	7.7	0.74	1.59	2	6	8	10	22	53
0.66	0.4	2.174	7.04	7.88	0.77	1.63	2	6	7	10	20	54
0.68	0.41	2.356	7.21	8.05	0.79	1.65	2	6	7	10	20	56
0.7	0.42	2.547	7.38	8.22	0.81	1.7	1	6	6	9	20	58
0.72	0.43	2.747	7.54	8.4	0.84	1.74	1	5	6	10	18	59
0.74	0.44	2.957	7.71	8.57	0.86	1.77	1	5	5	10	19	60
0.76	0.45	3.177	7.88	8.74	0.89	1.81	1	5	5	9	18	62
0.78	0.47	3.407	8.05	8.92	0.91	1.85	1	5	5	9	19	61
0.8	0.48	3.647	8.22	9.09	0.93	1.91	1	4	5	9	18	63
0.82	0.49	3.897	8.4	9.28	0.96	1.93	1	4	5	8	19	64
0.84	0.49	4.158	8.6	9.48	0.98	1.97	1	4	5	9	18	65
0.86	0.5	4.429	8.79	9.68	1	2.05	1	3	4	9	17	65
0.88	0.51	4.711	8.99	9.88	1.03	2.1	1	3	4	9	18	65
0.9	0.52	5.005	9.19	10.08	1.05	2.13	1	3	4	9	17	65
0.92	0.52	5.309	9.47	10.37	1.07	2.17	1	3	4	10	16	66
0.94	0.5	5.625	10.31	11.22	1.09	2.21	1	3	4	14	15	62
0.96	0.48	5.953	11.24	12.15	1.11	2.23	2	2	4	19	15	58
0.98	0.46	6.292	12.16	13.08	1.12	2.28	2	2	3	24	14	55
1	0.41	6.643	14.28	15.2	1.13	2.28	2	2	3	30	14	48
1.02	0.37	7.006	16.52	17.45	1.13	2.29	3	2	3	37	14	42
1.04	0.37	7.382	17.7	18.62	1.13	2.3	3	2	3	37	15	41
1.06	0.37	7.77	18.75	19.68	1.13	2.3	3	2	2	35	18	39
1.08	0.37	8.17	19.8	20.73	1.12	2.26	2	3	2	30	25	38

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
1.1	0.36	8.583	21.19	22.13	1.12	2.24	2	3	2	27	29	36
1.12	0.36	9.009	22.64	23.59	1.11	2.22	2	3	2	27	31	35
1.14	0.36	9.448	24.08	25.04	1.1	2.21	2	3	2	26	33	33
1.16	0.36	9.9	25.17	26.13	1.09	2.22	2	3	2	25	35	33
1.18	0.37	10.365	26.25	27.22	1.08	2.2	2	4	2	23	37	32
1.2	0.37	10.844	27.31	28.29	1.07	2.17	2	4	2	21	39	32
1.22	0.38	11.337	28.36	29.36	1.06	2.17	2	4	2	19	41	32
1.24	0.38	11.844	29.42	30.42	1.05	2.13	2	4	2	17	40	34
1.26	0.39	12.364	30.16	31.17	1.04	2.11	1	5	2	15	40	37
1.28	0.41	12.899	30.63	31.65	1.03	2.07	1	5	2	13	38	41
1.3	0.42	13.448	31.03	32.06	1.03	2.06	1	5	2	11	36	44
1.32	0.44	14.011	31.43	32.46	1.02	2.05	1	6	2	7	37	47
1.34	0.45	14.589	31.83	32.87	1.02	2.05	1	6	2	6	37	49
1.36	0.47	15.182	32.22	33.28	1.01	2.06	1	6	2	6	33	52
1.38	0.48	15.789	32.62	33.68	1.01	2.04	1	6	2	5	30	56
1.4	0.49	16.412	33.02	34.09	1.01	2.04	0	6	3	5	27	59
1.42	0.51	17.049	33.42	34.5	1.01	2.04	0	6	3	5	24	62
1.44	0.52	17.703	33.81	34.9	1	2.05	1	5	3	7	21	64
1.46	0.54	18.371	34.21	35.31	1	2.03	0	5	3	4	20	67
1.48	0.55	19.056	34.61	35.72	1	2.05	0	5	3	5	18	69
1.5	0.56	19.756	35	36.12	1	2.04	1	5	3	5	14	72
1.52	0.58	20.472	35.4	36.53	1	2.04	0	4	4	5	13	73
1.54	0.59	21.204	35.8	36.94	1	2.05	1	4	4	6	11	75
1.56	0.6	21.952	36.35	37.49	1.01	2.02	0	4	5	4	10	76
1.58	0.61	22.717	37.13	38.28	1.01	2.03	1	3	5	5	10	76
1.6	0.61	23.498	38.23	39.39	1.01	2.05	1	3	5	7	10	74
1.62	0.61	24.296	39.33	40.5	1.01	2.03	1	3	5	8	10	74
1.64	0.62	25.11	40.43	41.61	1.01	2.04	1	3	5	9	9	73
1.66	0.62	25.942	41.59	42.78	1.01	2.05	1	2	5	11	9	71
1.68	0.62	26.791	42.77	43.96	1.01	2.06	1	2	5	12	10	69
1.7	0.62	27.656	43.95	45.15	1.01	2.04	1	2	5	11	11	69
1.72	0.63	28.54	45.13	46.34	1.01	2.05	1	2	5	12	12	68
1.74	0.63	29.441	46.31	47.52	1.01	2.03	1	2	6	11	14	66
1.76	0.64	30.359	47.48	48.71	1.01	2.05	1	2	6	11	15	65
1.78	0.64	31.295	48.66	49.9	1.01	2.06	1	2	6	11	16	65
1.8	0.64	32.249	49.84	51.08	1	2.02	1	2	6	10	16	65
1.82	0.65	33.221	50.91	52.16	1	2.05	1	2	6	10	17	64
1.84	0.66	34.212	51.83	53.09	1	2.05	1	2	5	10	17	63
1.86	0.67	35.221	52.6	53.87	1	2.03	1	3	6	9	17	64
1.88	0.68	36.248	53.37	54.65	1	2.03	1	3	6	8	18	65
1.9	0.69	37.294	54.14	55.43	1	2	1	3	6	7	17	66
1.92	0.7	38.358	54.91	56.22	1	2.06	1	3	5	8	19	65
1.94	0.71	39.614	55.68	57	1	2.04	1	3	6	6	17	67
1.96	0.72	40.999	56.45	57.78	1.01	2.04	1	3	6	6	18	68
1.98	0.73	42.41	57.22	58.56	1.02	2.08	1	3	5	6	17	68
2	0.74	43.849	57.99	59.34	1.02	2.09	1	3	5	6	17	68
2.02	0.75	45.316	58.76	60.12	1.03	2.08	1	3	5	5	15	71
2.04	0.76	46.809	59.52	60.9	1.03	2.09	1	3	5	5	13	72
2.06	0.77	48.33	60.29	61.68	1.04	2.1	1	3	5	5	13	73
2.08	0.77	49.878	61.77	63.17	1.05	2.14	1	3	5	6	13	73
2.1	0.77	51.454	63.5	64.92	1.05	2.14	1	3	5	7	12	73
2.12	0.77	53.058	65.23	66.66	1.06	2.14	1	3	5	8	12	72
2.14	0.77	54.689	66.96	68.4	1.06	2.13	1	2	5	8	13	71
2.16	0.77	56.349	68.71	70.16	1.06	2.17	1	2	5	9	13	69
2.18	0.77	58.037	70.47	71.93	1.07	2.14	1	2	5	9	12	71
2.2	0.77	59.753	72.23	73.7	1.07	2.18	1	2	5	11	13	69

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
2.22	0.77	61.497	73.99	75.47	1.08	2.17	1	2	5	9	14	69
2.24	0.77	63.269	75.75	77.24	1.08	2.18	1	2	5	10	15	67
2.26	0.78	65.07	77.5	79.01	1.08	2.19	1	2	5	10	15	67
2.28	0.78	66.9	78.81	80.33	1.08	2.17	1	2	5	9	16	67
2.3	0.79	68.759	80.09	81.62	1.08	2.17	1	2	5	8	17	67
2.32	0.8	70.646	81.59	83.13	1.09	2.17	1	2	5	8	16	68
2.34	0.8	72.562	83.2	84.75	1.09	2.19	1	2	5	8	17	67
2.36	0.81	74.507	84.81	86.37	1.09	2.21	1	2	5	9	17	66
2.38	0.81	76.482	86.42	87.99	1.09	2.21	1	2	5	8	17	67
2.4	0.82	78.485	88.04	89.61	1.09	2.17	1	2	5	7	16	69
2.42	0.82	80.518	89.65	91.23	1.09	2.16	1	2	5	7	15	70
2.44	0.83	82.58	91.26	92.85	1.1	2.19	1	2	5	7	16	69
2.46	0.83	84.672	92.87	94.47	1.1	2.18	1	2	5	7	16	70
2.48	0.84	86.793	94.48	96.09	1.1	2.22	1	2	5	7	15	70
2.5	0.84	88.944	96.12	97.74	1.1	2.18	1	2	5	7	14	71
2.52	0.85	91.125	97.77	99.4	1.1	2.21	1	2	5	8	14	70
2.54	0.85	93.336	99.42	101.06	1.1	2.21	1	2	5	7	14	71
2.56	0.86	95.577	101.07	102.72	1.1	2.22	1	3	5	7	15	70
2.58	0.87	97.848	102.73	104.39	1.1	2.24	1	3	5	7	15	70
2.6	0.87	100.149	104.51	106.18	1.1	2.2	1	3	5	6	13	72
2.62	0.88	102.48	106.24	107.92	1.1	2.24	1	2	5	7	13	72
2.64	0.87	104.842	109.58	111.26	1.1	2.21	1	2	5	8	14	71
2.66	0.86	107.234	113	114.69	1.1	2.23	1	2	5	9	14	69
2.68	0.86	109.657	116.41	118.12	1.1	2.17	1	2	5	8	14	70
2.7	0.86	112.11	119.48	121.19	1.1	2.21	1	2	5	10	15	68
2.72	0.86	114.594	122.01	123.73	1.1	2.18	1	2	5	9	15	68
2.74	0.86	117.109	124.55	126.27	1.09	2.2	1	2	5	10	14	68
2.76	0.86	119.654	127.08	128.82	1.09	2.19	1	2	5	10	14	68
2.78	0.87	122.231	129.62	131.36	1.09	2.21	1	2	5	10	15	67
2.8	0.87	124.839	132.15	133.9	1.09	2.19	1	2	5	9	14	68
2.82	0.87	127.478	134.69	136.45	1.09	2.19	1	2	5	9	14	68
2.84	0.88	130.148	136.94	138.71	1.08	2.21	1	2	5	9	15	68
2.86	0.89	132.849	137.61	139.38	1.08	2.19	1	2	5	8	14	70
2.88	0.91	135.582	138.27	140.05	1.08	2.19	1	2	5	7	14	71
2.9	0.92	138.346	138.93	140.72	1.08	2.2	1	3	5	7	14	71
2.92	0.94	141.142	139.6	141.39	1.08	2.18	1	2	5	6	13	73
2.94	0.96	143.97	140.26	142.06	1.07	2.18	0	3	5	5	13	74
2.96	0.97	146.829	140.92	142.73	1.07	2.18	0	2	6	5	13	74
2.98	0.99	149.72	141.59	143.4	1.07	2.2	0	2	6	4	12	75
3	1	152.643	142.01	143.82	1.07	2.18	0	2	6	3	11	77
3.02	1.02	155.598	142.26	144.08	1.07	2.21	0	2	6	2	11	78
3.04	1.04	158.585	142.52	144.35	1.07	2.22	0	2	6	2	10	80
3.06	1.06	161.604	142.78	144.61	1.07	2.2	0	2	6	1	9	81
3.08	1.08	164.655	143.04	144.87	1.07	2.22	0	2	6	2	8	81
3.1	1.09	167.738	143.3	145.14	1.07	2.21	0	2	7	1	7	83
3.12	1.11	170.854	143.56	145.4	1.07	2.19	0	2	7	1	6	84
3.14	1.13	174.003	144.15	145.99	1.07	2.19	0	2	7	1	6	84
3.16	1.14	177.184	145.52	147.37	1.07	2.19	0	2	7	2	6	84
3.18	1.15	180.397	146.88	148.74	1.07	2.2	0	2	7	2	6	84
3.2	1.16	183.643	148.19	150.07	1.07	2.18	0	2	7	1	5	85
3.22	1.17	186.922	149.51	151.41	1.07	2.21	0	1	7	2	5	84
3.24	1.17	190.234	150.83	152.75	1.07	2.21	0	1	7	3	5	84
3.26	1.18	193.578	152.15	154.09	1.07	2.22	0	1	7	3	5	83
3.28	1.19	196.956	153.47	155.42	1.07	2.21	0	1	7	3	4	84
3.3	1.21	200.367	154.33	156.31	1.07	2.24	0	1	8	3	5	83
3.32	1.22	203.81	155.17	157.17	1.08	2.2	0	1	8	3	5	84

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
3.34	1.23	207.287	156.01	158.03	1.08	2.22	0	1	8	3	4	84
3.36	1.25	210.798	156.85	158.89	1.08	2.26	0	1	8	4	5	82
3.38	1.27	214.341	157.06	159.11	1.08	2.28	0	1	8	4	5	82
3.4	1.28	217.918	157.23	159.3	1.08	2.28	0	1	8	3	4	84
3.42	1.3	221.529	157.4	159.48	1.08	2.28	0	1	8	3	4	84
3.44	1.32	225.173	157.57	159.67	1.08	2.29	0	1	8	3	4	84
3.46	1.34	228.85	157.73	159.86	1.08	2.27	0	1	8	2	4	84
3.48	1.36	232.561	157.9	160.05	1.08	2.26	0	1	8	2	3	86
3.5	1.38	236.307	158.07	160.23	1.09	2.27	0	1	8	1	3	87
3.52	1.4	240.086	158.24	160.42	1.09	2.28	0	1	8	1	3	87
3.54	1.41	243.898	158.41	160.61	1.09	2.29	0	1	8	1	3	87
3.56	1.43	247.745	158.58	160.8	1.09	2.29	0	1	8	1	3	87
3.58	1.45	251.626	158.75	160.98	1.09	2.29	0	1	8	1	3	87
3.6	1.47	255.541	158.92	161.17	1.09	2.3	0	1	8	1	3	87
3.62	1.49	259.49	159.09	161.36	1.1	2.3	0	1	8	0	2	88
3.64	1.51	263.474	159.26	161.55	1.1	2.3	0	1	9	0	2	88
3.66	1.53	267.491	159.43	161.74	1.1	2.32	0	1	8	1	2	88
3.68	1.54	271.544	159.6	161.92	1.1	2.33	0	1	8	1	2	88
3.7	1.56	275.63	159.77	162.11	1.1	2.33	0	1	9	1	2	88
3.72	1.58	279.751	159.94	162.3	1.11	2.34	0	1	9	0	1	88
3.74	1.6	283.907	160.1	162.49	1.11	2.35	0	1	9	1	2	88
3.76	1.62	288.097	160.27	162.67	1.11	2.35	0	0	9	1	2	88
3.78	1.64	292.322	160.44	162.86	1.11	2.39	0	0	9	1	2	88
3.8	1.65	296.582	160.61	163.05	1.12	2.39	0	0	9	1	2	88
3.82	1.67	300.877	160.78	163.24	1.12	2.39	0	0	9	1	1	89
3.84	1.69	305.207	160.95	163.42	1.12	2.38	0	0	9	0	1	89
3.86	1.71	309.571	161.12	163.61	1.12	2.38	0	0	9	0	1	89
3.88	1.73	313.971	161.26	163.77	1.13	2.39	0	0	9	0	1	90
3.9	1.75	318.406	161.36	163.89	1.13	2.4	0	0	9	0	1	90
3.92	1.76	322.876	161.46	164	1.13	2.43	0	0	9	1	1	89
3.94	1.78	327.381	161.55	164.12	1.14	2.41	0	0	9	0	1	90
3.96	1.8	331.921	161.65	164.24	1.14	2.45	0	0	9	1	1	89
3.98	1.82	336.497	161.75	164.35	1.14	2.45	0	0	9	1	1	89
4	1.84	341.108	161.84	164.47	1.15	2.46	0	0	9	1	1	89

SvS=Slow very Shallow; SS=Slow Shallow; SD=Slow Deep; FvS=Fast very Shallow; FS=Fast Shallow; FD=Fast Deep (for velocity and depth ranges refer to Birkhead 2010)

Table 3.8: Ecologically relevant hydraulic indicators at 5_Mogalakwena

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.02	0.01	0	0.46	0.46	0.01	0.05	100	0	0	0	0	0
0.04	0.01	0.001	2.1	2.1	0.02	0.08	100	0	0	0	0	0
0.06	0.03	0.002	3.23	3.25	0.03	0.1	100	0	0	0	0	0
0.08	0.04	0.006	3.8	3.83	0.04	0.14	100	0	0	0	0	0
0.1	0.05	0.012	4.31	4.37	0.05	0.19	100	0	0	0	0	0
0.12	0.07	0.022	4.44	4.53	0.07	0.24	89	10	0	1	0	0
0.14	0.09	0.037	4.58	4.69	0.09	0.32	54	43	0	2	2	0
0.16	0.11	0.057	4.71	4.85	0.11	0.39	29	64	0	2	5	0
0.18	0.12	0.085	4.84	5.01	0.14	0.48	19	70	0	2	8	0
0.2	0.14	0.12	5.03	5.23	0.17	0.58	13	71	0	3	14	0
0.22	0.13	0.165	6.01	6.24	0.2	0.68	20	57	0	6	17	0
0.24	0.13	0.22	7.37	7.62	0.23	0.77	27	43	0	12	19	0
0.26	0.12	0.287	8.91	9.2	0.26	0.84	31	33	0	18	19	0

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.28	0.12	0.367	11.13	11.44	0.28	0.89	34	26	0	23	18	0
0.3	0.13	0.461	12.08	12.4	0.3	0.94	33	24	0	25	18	0
0.32	0.13	0.571	13.88	14.21	0.32	1	30	22	0	28	18	2
0.34	0.12	0.698	16.76	17.1	0.33	1.03	28	22	0	28	15	7
0.36	0.11	0.844	22.18	22.54	0.34	1.04	28	20	0	30	14	7
0.38	0.11	1.009	28.16	28.52	0.34	1.02	30	19	0	31	13	7
0.4	0.12	1.196	29.74	30.1	0.33	1.03	29	21	0	29	14	7
0.42	0.13	1.406	32.02	32.39	0.34	1.05	28	22	0	28	15	7
0.44	0.15	1.641	32.41	32.79	0.34	1.05	23	27	0	23	20	7
0.46	0.17	1.901	32.54	32.92	0.35	1.1	15	33	0	16	28	7
0.48	0.19	2.19	32.67	33.06	0.36	1.12	7	40	0	8	37	8
0.5	0.21	2.507	32.79	33.19	0.37	1.16	4	43	0	4	40	9
0.52	0.23	2.855	32.92	33.32	0.38	1.21	2	42	1	2	43	10
0.54	0.25	3.235	33.05	33.46	0.4	1.27	1	40	2	1	44	12
0.56	0.26	3.65	33.18	33.59	0.42	1.29	0	37	4	0	42	16
0.58	0.28	4.1	33.3	33.73	0.43	1.34	1	33	4	1	40	20
0.6	0.3	4.588	33.44	33.87	0.45	1.39	1	31	5	1	39	24
0.62	0.32	5.115	33.59	34.02	0.47	1.42	0	29	5	1	37	28
0.64	0.34	5.682	33.73	34.18	0.5	1.45	0	28	5	1	34	33
0.66	0.36	6.293	33.88	34.33	0.52	1.51	1	26	4	2	24	44
0.68	0.38	6.947	34.03	34.48	0.54	1.55	1	24	4	2	15	54
0.7	0.39	7.648	34.18	34.64	0.57	1.55	0	23	4	1	8	64
0.72	0.41	8.397	34.33	34.79	0.59	1.6	0	21	5	1	5	69
0.74	0.43	9.195	34.48	34.95	0.62	1.65	0	18	5	2	3	71
0.76	0.45	10.045	34.63	35.1	0.65	1.68	0	16	6	1	2	74
0.78	0.47	10.948	34.78	35.25	0.67	1.7	0	14	6	1	3	75
0.8	0.49	11.907	34.93	35.41	0.7	1.74	1	12	7	2	3	75
0.82	0.5	12.922	35.07	35.56	0.73	1.75	0	11	8	1	3	77
0.84	0.52	13.997	35.22	35.72	0.76	1.78	0	8	9	1	3	78
0.86	0.54	15.133	35.37	35.87	0.79	1.86	0	6	10	2	3	79
0.88	0.56	16.331	35.52	36.03	0.83	1.89	0	4	11	2	3	80
0.9	0.57	17.594	35.66	36.17	0.86	1.89	0	2	12	1	3	82
0.92	0.59	18.924	35.84	36.36	0.89	1.97	0	1	11	2	4	81
0.94	0.61	20.322	36.19	36.71	0.93	2	0	1	11	2	4	82
0.96	0.62	21.791	36.53	37.06	0.96	2.07	0	1	10	3	4	82
0.98	0.63	23.333	36.88	37.41	1	2.1	0	1	9	3	4	83
1	0.65	24.949	37.23	37.76	1.03	2.14	0	1	9	3	4	84
1.02	0.66	26.642	37.57	38.11	1.07	2.21	0	1	8	3	4	84
1.04	0.68	28.413	37.92	38.46	1.11	2.3	0	1	7	4	5	83
1.06	0.69	30.265	38.27	38.81	1.15	2.35	0	1	7	4	5	84
1.08	0.7	32.2	38.61	39.16	1.19	2.42	0	1	6	4	6	83
1.1	0.72	33.814	38.91	39.47	1.21	2.44	0	1	6	3	5	84
1.12	0.73	35.4	39.21	39.77	1.23	2.5	0	1	6	4	6	83
1.14	0.75	37.029	39.51	40.08	1.26	2.55	0	1	5	4	6	83
1.16	0.76	38.699	39.81	40.38	1.28	2.57	0	1	5	3	7	84
1.18	0.77	40.412	40.11	40.68	1.3	2.62	0	1	5	3	7	84
1.2	0.79	42.168	40.41	40.99	1.32	2.69	0	1	5	4	7	83
1.22	0.81	43.968	40.61	41.19	1.34	2.73	0	1	5	3	8	84
1.24	0.82	45.81	40.75	41.34	1.37	2.77	0	1	5	2	8	85
1.26	0.84	47.696	40.89	41.49	1.39	2.78	0	1	5	1	8	85
1.28	0.86	49.627	41.03	41.64	1.41	2.85	0	1	5	1	8	86
1.3	0.87	51.601	41.17	41.78	1.43	2.9	0	1	5	1	7	87
1.32	0.89	53.62	41.31	41.93	1.46	2.95	0	1	4	1	7	87
1.34	0.91	55.684	41.45	42.08	1.48	3.01	0	1	4	2	6	87
1.36	0.92	57.793	41.59	42.23	1.5	3.06	0	1	4	2	6	87
1.38	0.94	59.947	41.73	42.38	1.53	3.11	0	1	4	2	5	89

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
1.4	0.96	62.147	41.87	42.53	1.55	3.15	0	1	4	2	5	88
1.42	0.97	64.392	42.01	42.67	1.57	3.2	0	1	4	2	4	89
1.44	0.99	66.683	42.16	42.82	1.6	3.22	0	1	4	2	4	89
1.46	1.01	69.021	42.3	42.97	1.62	3.24	0	1	4	1	4	90
1.48	1.02	71.405	42.44	43.12	1.64	3.3	0	0	4	1	3	92
1.5	1.04	73.836	42.58	43.27	1.67	3.35	0	0	4	1	3	92
1.52	1.06	76.314	42.72	43.42	1.69	3.37	0	0	4	1	3	92
1.54	1.07	78.84	42.84	43.54	1.71	3.44	0	0	4	1	3	92
1.56	1.09	81.412	42.95	43.66	1.74	3.5	0	0	4	1	3	92
1.58	1.11	84.033	43.06	43.78	1.76	3.54	0	0	4	1	3	92
1.6	1.13	86.701	43.17	43.9	1.78	3.6	0	0	4	1	3	93
1.62	1.14	89.417	43.28	44.02	1.81	3.66	0	0	4	2	3	92
1.64	1.16	92.182	43.39	44.13	1.83	3.73	0	0	4	1	3	92
1.66	1.18	94.996	43.5	44.25	1.85	3.78	0	0	4	1	3	92
1.68	1.19	97.858	43.61	44.37	1.88	3.84	0	0	3	2	2	92
1.7	1.21	100.769	43.72	44.49	1.9	3.9	0	0	3	2	2	92
1.72	1.23	103.73	43.82	44.6	1.93	3.88	0	0	3	1	2	93
1.74	1.25	106.74	43.93	44.72	1.95	3.94	0	0	3	1	2	93
1.76	1.26	109.8	44.04	44.84	1.97	4	0	0	3	1	2	93
1.78	1.28	112.909	44.15	44.96	2	4.05	0	0	3	1	2	93
1.8	1.3	116.069	44.26	45.08	2.02	4.14	0	0	3	2	2	93
1.82	1.31	119.279	44.37	45.19	2.05	4.15	0	0	3	2	2	93
1.84	1.33	122.54	44.48	45.31	2.07	4.22	0	0	3	2	2	93
1.86	1.35	125.852	44.59	45.43	2.1	4.28	0	0	3	2	2	93
1.88	1.36	129.214	44.7	45.55	2.12	4.33	0	0	3	2	2	93
1.9	1.38	132.628	44.81	45.66	2.15	4.33	0	0	3	1	2	94
1.92	1.4	136.093	44.92	45.78	2.17	4.37	0	0	3	1	2	94
1.94	1.41	139.609	45.03	45.9	2.19	4.38	0	0	3	1	2	94
1.96	1.43	143.178	45.14	46.02	2.22	4.45	0	0	3	1	2	94
1.98	1.45	146.798	45.25	46.14	2.24	4.5	0	0	3	1	2	94
2	1.46	150.47	45.36	46.25	2.27	4.6	0	0	3	1	2	93
2.02	1.48	154.195	45.47	46.37	2.29	4.65	0	0	3	1	2	94
2.04	1.5	157.973	45.58	46.49	2.32	4.69	0	0	3	1	2	94
2.06	1.51	161.803	45.69	46.61	2.34	4.73	0	0	3	1	2	94
2.08	1.53	165.686	45.8	46.72	2.37	4.75	0	0	3	1	2	95
2.1	1.54	169.622	45.92	46.86	2.39	4.85	0	0	3	1	2	94
2.12	1.56	173.612	46.1	47.04	2.42	4.85	0	0	3	1	1	95
2.14	1.57	177.655	46.27	47.22	2.44	4.89	0	0	3	1	1	95
2.16	1.59	181.752	46.45	47.41	2.47	5.01	0	0	3	1	3	93
2.18	1.6	185.902	46.63	47.59	2.49	4.99	0	0	3	1	3	93
2.2	1.61	190.107	46.81	47.78	2.52	5.06	0	0	3	1	3	93
2.22	1.63	194.366	46.98	47.96	2.54	5.17	0	0	3	2	3	92
2.24	1.64	198.679	47.16	48.15	2.57	5.23	0	0	3	2	3	92
2.26	1.66	203.048	47.34	48.33	2.59	5.23	0	0	3	1	3	93
2.28	1.67	207.47	47.51	48.52	2.62	5.33	0	0	3	2	3	92
2.3	1.68	211.948	47.69	48.7	2.64	5.38	0	0	2	2	3	93
2.32	1.7	216.481	47.87	48.88	2.67	5.36	0	0	3	1	3	93
2.34	1.71	221.07	48.05	49.07	2.69	5.42	0	0	3	1	3	93
2.36	1.72	225.714	48.22	49.25	2.71	5.53	0	0	2	2	4	92
2.38	1.74	230.413	48.4	49.44	2.74	5.6	0	0	2	2	4	92
2.4	1.75	235.169	48.58	49.62	2.76	5.61	0	0	2	1	3	93
2.42	1.76	239.98	48.76	49.81	2.79	5.73	0	0	2	2	4	92
2.44	1.78	244.848	48.93	49.99	2.81	5.77	0	0	2	2	4	92
2.46	1.79	249.772	49.11	50.17	2.84	5.71	0	0	2	1	3	93
2.48	1.81	254.753	49.29	50.36	2.86	5.78	0	0	2	1	3	93
2.5	1.82	259.79	49.46	50.54	2.89	5.9	0	0	2	2	3	92

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
2.52	1.83	264.885	49.64	50.73	2.91	5.89	0	0	2	1	3	93
2.54	1.85	270.036	49.82	50.91	2.94	5.95	0	0	2	1	3	93
2.56	1.86	275.245	50	51.1	2.96	6.07	0	0	2	2	4	92
2.58	1.87	280.511	50.17	51.28	2.99	6.1	0	0	2	2	4	92
2.6	1.89	285.834	50.35	51.47	3.01	6.11	0	0	2	1	4	93
2.62	1.9	291.215	50.53	51.65	3.03	6.13	0	0	2	1	4	93
2.64	1.91	296.655	50.69	51.82	3.06	6.25	0	0	2	2	4	92
2.66	1.93	302.152	50.86	52	3.08	6.25	0	0	2	1	4	93
2.68	1.94	307.707	51.03	52.18	3.11	6.3	0	0	2	1	3	93
2.7	1.95	313.321	51.2	52.36	3.13	6.41	0	0	2	2	4	92

SvS=Slow very Shallow; SS=Slow Shallow; SD=Slow Deep; FvS=Fast very Shallow; FS=Fast Shallow; FD=Fast Deep (for velocity and depth ranges refer to Birkhead 2010)

Table 3.9: Ecologically relevant hydraulic indicators at 6_Kolope

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.02	0.01	0	0.72	0.73	0.04	0.14	100	0	0	0	0	0
0.04	0.02	0.002	1.4	1.41	0.07	0.21	100	0	0	0	0	0
0.06	0.04	0.006	1.71	1.72	0.1	0.28	98	0	0	2	0	0
0.08	0.05	0.012	2.02	2.03	0.12	0.33	97	0	0	3	0	0
0.1	0.06	0.019	2.33	2.34	0.14	0.37	94	1	0	5	0	0
0.12	0.07	0.029	2.63	2.65	0.15	0.41	67	26	0	5	2	0
0.14	0.08	0.042	2.94	2.96	0.17	0.44	47	43	0	6	5	0
0.16	0.09	0.057	3.25	3.27	0.19	0.47	40	46	0	6	8	0
0.18	0.11	0.075	3.54	3.57	0.2	0.5	35	46	0	8	11	0
0.2	0.12	0.097	3.75	3.78	0.22	0.53	28	48	0	9	15	0
0.22	0.13	0.122	3.92	3.96	0.23	0.56	23	49	0	9	20	0
0.24	0.15	0.152	4.04	4.08	0.25	0.6	18	48	0	9	25	0
0.26	0.17	0.184	4.15	4.2	0.27	0.62	13	48	0	8	31	0
0.28	0.18	0.219	4.26	4.32	0.28	0.66	10	46	0	8	36	0
0.3	0.2	0.256	4.38	4.44	0.3	0.69	7	46	0	7	39	1
0.32	0.21	0.297	4.49	4.56	0.31	0.72	6	43	0	7	36	8
0.34	0.23	0.34	4.6	4.68	0.33	0.75	6	41	0	6	31	16
0.36	0.24	0.386	4.71	4.8	0.34	0.77	5	41	0	6	29	20
0.38	0.25	0.434	4.83	4.92	0.35	0.8	5	37	0	7	27	24
0.4	0.27	0.485	4.94	5.04	0.37	0.82	4	37	0	6	25	28
0.42	0.28	0.539	5.05	5.16	0.38	0.85	4	34	0	7	22	32
0.44	0.3	0.596	5.16	5.29	0.39	0.86	4	33	0	6	20	36
0.46	0.31	0.656	5.28	5.41	0.4	0.9	4	32	0	7	18	39
0.48	0.32	0.721	5.35	5.49	0.42	0.91	3	31	0	6	16	44
0.5	0.34	0.789	5.43	5.58	0.43	0.94	3	29	1	5	15	46
0.52	0.35	0.859	5.51	5.67	0.44	0.97	3	24	4	6	14	49
0.54	0.37	0.933	5.59	5.75	0.45	0.98	2	21	7	5	14	50
0.56	0.38	1.009	5.67	5.84	0.46	1.01	2	19	8	4	14	52
0.58	0.4	1.087	5.74	5.93	0.47	1.04	2	16	10	5	14	54
0.6	0.41	1.169	5.82	6.02	0.49	1.05	2	15	11	5	13	55
0.62	0.43	1.253	5.9	6.1	0.5	1.08	1	13	12	4	14	56
0.64	0.44	1.34	5.98	6.19	0.51	1.1	2	11	12	4	13	58
0.66	0.46	1.43	6.05	6.28	0.52	1.12	2	10	13	5	12	59
0.68	0.47	1.523	6.13	6.37	0.53	1.14	1	9	14	4	11	60
0.7	0.48	1.618	6.21	6.45	0.54	1.15	1	8	14	4	11	61
0.72	0.5	1.716	6.29	6.54	0.55	1.18	1	7	14	5	10	62
0.74	0.51	1.817	6.36	6.63	0.56	1.18	1	7	14	4	10	63

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.76	0.52	1.912	6.49	6.76	0.56	1.2	2	6	14	5	9	64
0.78	0.53	2.002	6.66	6.94	0.57	1.23	2	6	14	7	8	63
0.8	0.53	2.094	6.84	7.13	0.57	1.22	2	6	14	7	9	63
0.82	0.54	2.191	7.02	7.31	0.58	1.23	2	6	14	7	9	62
0.84	0.55	2.291	7.2	7.49	0.58	1.23	2	5	14	8	9	61
0.86	0.55	2.395	7.37	7.68	0.59	1.24	2	5	14	9	9	61
0.88	0.56	2.503	7.55	7.86	0.59	1.25	2	5	13	9	10	61
0.9	0.57	2.615	7.73	8.04	0.6	1.27	2	5	13	9	11	60
0.92	0.57	2.731	7.91	8.23	0.6	1.27	2	5	13	9	11	59
0.94	0.58	2.851	8.09	8.41	0.61	1.29	2	5	13	9	12	59
0.96	0.59	2.977	8.26	8.59	0.61	1.3	2	5	13	8	13	60
0.98	0.6	3.107	8.42	8.76	0.62	1.31	2	5	13	7	14	59
1	0.61	3.242	8.59	8.94	0.62	1.33	2	5	12	8	15	58
1.02	0.61	3.382	8.75	9.11	0.63	1.34	2	5	12	8	15	58
1.04	0.62	3.571	8.91	9.28	0.64	1.34	2	5	12	7	15	59
1.06	0.63	3.766	9.08	9.45	0.66	1.37	2	5	11	7	15	60
1.08	0.64	3.968	9.24	9.62	0.67	1.4	1	5	11	7	15	61
1.1	0.65	4.177	9.41	9.8	0.68	1.43	2	5	10	8	15	61
1.12	0.66	4.393	9.58	9.98	0.7	1.44	1	5	10	8	15	61
1.14	0.66	4.615	9.79	10.19	0.71	1.45	1	5	10	7	15	63
1.16	0.67	4.845	10	10.41	0.73	1.49	1	4	9	7	15	63
1.18	0.67	5.083	10.21	10.63	0.74	1.51	1	4	9	8	14	64
1.2	0.68	5.327	10.42	10.85	0.75	1.54	1	4	8	8	14	64
1.22	0.69	5.579	10.63	11.07	0.76	1.57	1	4	8	9	14	64
1.24	0.69	5.838	10.84	11.29	0.78	1.59	1	4	8	9	13	65
1.26	0.7	6.105	11.05	11.5	0.79	1.62	1	4	7	9	13	65
1.28	0.71	6.38	11.26	11.72	0.8	1.64	1	4	7	8	15	65
1.3	0.71	6.663	11.47	11.94	0.81	1.65	1	4	7	7	15	66
1.32	0.72	6.953	11.69	12.16	0.83	1.67	1	4	7	7	15	67
1.34	0.73	7.252	11.9	12.38	0.84	1.7	1	3	7	7	15	67
1.36	0.73	7.558	12.11	12.59	0.85	1.72	1	3	7	7	15	67
1.38	0.74	7.873	12.4	12.9	0.86	1.74	1	3	6	8	14	67
1.4	0.72	8.196	12.95	13.45	0.87	1.75	1	3	6	9	15	65
1.42	0.71	8.528	13.5	14.01	0.88	1.77	1	3	6	11	14	64
1.44	0.71	8.868	14.05	14.57	0.89	1.79	1	3	6	13	13	64
1.46	0.7	9.216	14.6	15.13	0.9	1.82	2	3	6	15	13	62
1.48	0.69	9.574	15.15	15.68	0.91	1.83	2	3	6	15	13	62
1.5	0.69	9.94	15.71	16.24	0.92	1.85	2	3	5	14	15	60
1.52	0.69	10.315	16.08	16.62	0.93	1.88	1	3	5	14	16	60
1.54	0.7	10.699	16.4	16.95	0.93	1.89	1	3	5	13	17	60
1.56	0.71	11.092	16.73	17.28	0.94	1.89	1	3	5	10	20	60
1.58	0.71	11.494	17.05	17.62	0.95	1.93	1	3	5	10	20	60
1.6	0.72	11.905	17.38	17.95	0.95	1.94	1	3	5	8	22	60
1.62	0.72	12.326	17.7	18.28	0.96	1.94	1	3	5	8	22	61
1.64	0.73	12.756	18.03	18.61	0.97	1.98	1	3	5	8	22	61
1.66	0.74	13.195	18.35	18.95	0.97	1.97	1	3	5	7	21	62
1.68	0.75	13.644	18.68	19.28	0.98	1.99	1	3	5	7	21	63
1.7	0.75	14.103	19.01	19.61	0.99	2.01	1	3	5	7	20	64
1.72	0.76	14.572	19.33	19.94	0.99	1.99	1	3	5	6	20	64
1.74	0.77	15.051	19.66	20.28	1	2	1	3	5	6	19	66
1.76	0.78	15.539	19.87	20.5	1	2.04	1	3	5	7	18	67
1.78	0.79	16.038	20.01	20.64	1.01	2.05	1	3	5	6	17	69
1.8	0.81	16.547	20.14	20.79	1.02	2.07	0	3	5	5	16	70
1.82	0.82	17.066	20.28	20.93	1.02	2.09	0	3	5	4	16	72
1.84	0.84	17.595	20.42	21.08	1.03	2.1	0	3	5	4	15	73
1.86	0.85	18.135	20.55	21.22	1.04	2.12	0	3	5	3	14	75

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
1.88	0.87	18.685	20.69	21.37	1.04	2.13	0	3	5	3	13	76
1.9	0.88	19.246	20.83	21.51	1.05	2.15	0	3	5	3	12	77
1.92	0.89	19.818	20.96	21.66	1.06	2.15	0	3	5	3	11	78
1.94	0.91	20.401	21.1	21.81	1.07	2.16	0	2	5	3	10	79
1.96	0.92	20.994	21.25	21.96	1.07	2.17	0	2	5	2	10	80
1.98	0.93	21.598	21.4	22.12	1.08	2.19	0	2	6	3	8	81
2	0.95	22.214	21.56	22.28	1.09	2.2	0	2	6	3	7	83
2.02	0.96	22.84	21.71	22.43	1.09	2.24	0	2	6	3	7	82
2.04	0.97	23.478	21.86	22.59	1.1	2.25	0	2	6	3	6	83
2.06	0.99	24.127	22.01	22.75	1.11	2.27	0	2	6	3	6	83
2.08	1	24.788	22.16	22.9	1.12	2.29	0	1	6	3	6	83
2.1	1.01	25.46	22.31	23.06	1.13	2.28	0	1	6	3	6	84
2.12	1.03	26.143	22.46	23.22	1.13	2.3	0	1	6	3	6	84
2.14	1.04	26.838	22.61	23.37	1.14	2.32	0	1	6	3	6	84
2.16	1.05	27.545	22.76	23.53	1.15	2.34	0	1	6	3	6	84
2.18	1.07	28.264	22.91	23.69	1.16	2.33	0	1	6	3	5	85
2.2	1.08	28.995	23.06	23.85	1.16	2.38	0	1	6	3	5	84
2.22	1.09	29.738	23.21	24	1.17	2.4	0	1	6	3	6	84
2.24	1.11	30.493	23.36	24.16	1.18	2.41	0	1	6	3	6	84
2.26	1.12	31.26	23.51	24.32	1.19	2.4	0	1	6	2	6	85
2.28	1.13	32.04	23.66	24.47	1.2	2.42	0	1	6	2	6	85
2.3	1.14	32.831	23.81	24.63	1.21	2.44	0	1	6	3	6	84
2.32	1.16	33.636	23.96	24.79	1.21	2.47	0	1	6	3	6	84
2.34	1.17	34.452	24.11	24.94	1.22	2.46	0	1	6	2	6	85
2.36	1.18	35.282	24.26	25.09	1.23	2.48	0	1	6	2	6	85
2.38	1.2	36.124	24.35	25.19	1.24	2.51	0	1	5	3	5	86
2.4	1.21	36.979	24.44	25.29	1.25	2.53	0	1	5	3	5	86
2.42	1.23	37.847	24.53	25.39	1.26	2.56	0	1	5	2	5	86
2.44	1.24	38.728	24.62	25.49	1.26	2.55	0	1	6	2	5	87
2.46	1.26	39.622	24.71	25.59	1.27	2.6	0	1	5	2	5	86
2.48	1.28	40.529	24.8	25.68	1.28	2.59	0	1	5	2	4	88
2.5	1.29	41.449	24.89	25.78	1.29	2.6	0	1	5	1	4	88
2.52	1.31	42.382	24.98	25.88	1.3	2.64	0	1	5	2	5	88
2.54	1.32	43.329	25.07	25.98	1.31	2.64	0	1	5	1	4	88
2.56	1.34	44.29	25.16	26.08	1.32	2.66	0	1	5	1	4	89
2.58	1.35	45.264	25.25	26.18	1.33	2.68	0	1	5	1	4	89
2.6	1.37	46.252	25.34	26.28	1.34	2.73	0	1	5	2	4	89
2.62	1.38	47.253	25.43	26.37	1.34	2.74	0	1	5	2	4	89
2.64	1.4	48.268	25.52	26.47	1.35	2.75	0	1	5	2	4	89
2.66	1.41	49.297	25.61	26.57	1.36	2.74	0	1	5	1	3	90
2.68	1.43	50.34	25.7	26.67	1.37	2.76	0	1	5	2	3	90
2.7	1.44	51.398	25.79	26.77	1.38	2.77	0	0	5	1	3	91
2.72	1.46	52.469	25.88	26.87	1.39	2.8	0	0	5	1	3	91
2.74	1.47	53.554	25.97	26.97	1.4	2.86	0	0	5	2	3	90
2.76	1.49	54.654	26.06	27.07	1.41	2.88	0	0	5	2	3	90
2.78	1.5	55.769	26.15	27.16	1.42	2.86	0	0	5	1	3	91
2.8	1.52	56.897	26.24	27.26	1.43	2.89	0	0	5	1	3	91
2.82	1.53	58.041	26.33	27.36	1.44	2.94	0	0	5	1	4	90
2.84	1.55	59.199	26.42	27.46	1.45	2.96	0	0	5	1	4	90
2.86	1.56	60.371	26.51	27.56	1.46	2.98	0	0	5	1	3	90
2.88	1.58	61.559	26.6	27.66	1.47	2.95	0	0	5	1	3	91
2.9	1.59	62.761	26.69	27.76	1.48	2.97	0	0	5	1	3	91
2.92	1.6	63.979	26.82	27.89	1.49	3.02	0	0	5	1	3	90
2.94	1.61	65.211	26.95	28.03	1.5	3.03	0	0	5	1	3	91
2.96	1.63	66.459	27.08	28.17	1.51	3.08	0	0	4	1	3	90
2.98	1.64	67.722	27.21	28.3	1.52	3.08	0	0	4	1	3	91

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
3	1.65	69	27.35	28.44	1.53	3.12	0	0	4	2	3	90
3.02	1.66	70.293	27.48	28.58	1.54	3.13	0	0	4	2	3	90
3.04	1.67	71.602	27.61	28.72	1.55	3.13	0	0	4	1	3	91
3.06	1.69	72.927	27.74	28.86	1.56	3.12	0	0	4	1	3	91
3.08	1.7	74.267	27.87	29	1.57	3.15	0	0	4	1	3	91
3.1	1.71	75.623	28.01	29.13	1.58	3.22	0	0	4	2	4	89
3.12	1.72	76.995	28.14	29.27	1.59	3.23	0	0	4	2	4	89
3.14	1.73	78.382	28.27	29.41	1.6	3.26	0	0	4	2	4	90
3.16	1.75	79.786	28.4	29.55	1.61	3.25	0	0	4	2	4	90
3.18	1.76	81.206	28.53	29.69	1.62	3.3	0	0	4	2	4	89
3.2	1.77	82.641	28.66	29.83	1.63	3.28	0	0	4	2	4	90
3.22	1.78	84.093	28.8	29.96	1.64	3.33	0	0	4	2	4	89
3.24	1.79	85.561	28.93	30.1	1.65	3.36	0	0	4	2	4	89
3.26	1.81	87.046	29.06	30.24	1.66	3.35	0	0	4	2	4	90
3.28	1.82	88.547	29.19	30.38	1.67	3.36	0	0	4	2	3	90
3.3	1.83	90.064	29.32	30.52	1.68	3.37	0	0	4	2	3	90
3.32	1.84	91.599	29.46	30.66	1.69	3.43	0	0	4	2	4	89
3.34	1.85	93.149	29.6	30.81	1.7	3.44	0	0	4	2	4	89
3.36	1.86	94.717	29.75	30.96	1.71	3.44	0	0	4	2	4	90
3.38	1.87	96.301	29.89	31.11	1.72	3.51	0	0	4	2	4	90
3.4	1.88	97.903	30.04	31.26	1.73	3.54	0	0	4	3	4	89
3.42	1.9	99.521	30.18	31.41	1.74	3.55	0	0	4	2	4	89
3.44	1.91	101.156	30.33	31.56	1.75	3.57	0	0	4	2	4	89
3.46	1.92	102.809	30.47	31.71	1.76	3.56	0	0	4	2	4	90
3.48	1.93	104.479	30.62	31.86	1.77	3.59	0	0	4	2	4	90
3.5	1.94	106.166	30.76	32.01	1.78	3.58	0	0	4	2	4	90

SvS=Slow very Shallow; SS=Slow Shallow; SD=Slow Deep; FvS=Fast very Shallow; FS=Fast Shallow; FD=Fast Deep (for velocity and depth ranges refer to Birkhead 2010)

Table 3.10: Ecologicall relevant hydraulic indicators at 7_Sand

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.02	0.01	0.001	2.62	2.62	0.02	0.08	100	0	0	0	0	0
0.04	0.02	0.004	5.25	5.25	0.04	0.12	100	0	0	0	0	0
0.06	0.03	0.011	7.87	7.87	0.05	0.16	100	0	0	0	0	0
0.08	0.04	0.024	10.5	10.5	0.06	0.19	100	0	0	0	0	0
0.1	0.05	0.045	12.66	12.66	0.07	0.22	99	1	0	0	0	0
0.12	0.06	0.073	15.45	15.46	0.08	0.25	82	17	0	1	0	0
0.14	0.07	0.111	18.24	18.25	0.09	0.27	70	29	0	1	0	0
0.16	0.08	0.163	20.31	20.34	0.1	0.3	60	37	0	2	1	0
0.18	0.09	0.229	22.08	22.12	0.11	0.33	50	47	0	2	2	0
0.2	0.11	0.308	23.85	23.9	0.12	0.36	43	52	0	2	2	0
0.22	0.12	0.401	25.62	25.68	0.13	0.39	37	58	0	2	3	0
0.24	0.13	0.51	27.38	27.46	0.14	0.42	30	63	0	2	5	0
0.26	0.15	0.653	27.79	27.89	0.16	0.46	25	66	0	3	7	0
0.28	0.17	0.818	27.86	27.97	0.17	0.5	18	69	0	3	10	0
0.3	0.19	1.001	27.92	28.05	0.19	0.54	12	70	0	3	15	0
0.32	0.21	1.203	27.99	28.13	0.21	0.58	7	70	0	2	19	2
0.34	0.23	1.425	28.06	28.21	0.22	0.61	2	72	0	1	21	5
0.36	0.25	1.667	28.12	28.29	0.24	0.65	0	68	0	0	22	9
0.38	0.27	1.929	28.19	28.37	0.26	0.69	1	63	0	0	23	14
0.4	0.28	2.213	28.26	28.45	0.28	0.72	0	59	0	0	22	19
0.42	0.3	2.52	28.32	28.53	0.29	0.75	0	55	0	0	19	25

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.44	0.32	2.85	28.39	28.61	0.31	0.79	0	52	0	0	17	31
0.46	0.34	3.205	28.46	28.69	0.33	0.82	0	48	0	0	14	38
0.48	0.36	3.586	28.52	28.78	0.35	0.86	0	44	0	1	12	43
0.5	0.38	4	28.59	28.86	0.37	0.89	0	41	1	0	9	49
0.52	0.4	4.369	28.66	28.94	0.38	0.91	0	36	4	0	6	55
0.54	0.42	4.755	28.72	29.02	0.4	0.94	0	31	7	0	3	59
0.56	0.44	5.161	28.79	29.1	0.41	0.97	0	26	10	0	1	63
0.58	0.46	5.584	28.86	29.18	0.42	1	1	21	12	1	1	64
0.6	0.48	6.026	28.92	29.26	0.44	1.02	0	18	15	0	1	66
0.62	0.49	6.487	28.99	29.34	0.45	1.04	0	14	17	0	1	67
0.64	0.51	6.967	29.06	29.42	0.47	1.08	0	11	18	1	1	68
0.66	0.53	7.466	29.12	29.5	0.48	1.11	0	9	19	1	1	70
0.68	0.54	7.984	29.62	30.01	0.5	1.12	0	7	20	1	2	70
0.7	0.54	8.522	31.1	31.5	0.51	1.14	2	4	20	5	1	67
0.72	0.55	9.079	31.49	31.89	0.52	1.16	2	3	21	5	1	68
0.74	0.57	9.656	31.76	32.16	0.54	1.19	2	1	21	6	2	67
0.76	0.58	10.253	32.03	32.44	0.55	1.2	2	1	20	6	2	69
0.78	0.6	10.869	32.3	32.71	0.57	1.25	2	1	20	6	3	68
0.8	0.61	11.506	32.56	32.98	0.58	1.26	1	2	19	4	5	69
0.82	0.63	12.162	32.83	33.26	0.59	1.29	1	2	18	3	7	69
0.84	0.64	12.839	33.1	33.53	0.61	1.31	1	3	18	2	8	70
0.86	0.66	13.537	33.37	33.8	0.62	1.34	1	2	17	3	8	69
0.88	0.67	14.255	33.64	34.07	0.63	1.34	0	3	16	2	9	70
0.9	0.68	14.993	33.91	34.35	0.65	1.36	0	2	16	2	10	70
0.92	0.7	15.753	34.18	34.62	0.66	1.41	1	3	15	3	10	70
0.94	0.71	16.533	34.44	34.89	0.67	1.42	0	2	15	2	10	71
0.96	0.73	17.334	34.71	35.17	0.69	1.43	1	2	14	3	8	72
0.98	0.74	18.156	34.98	35.44	0.7	1.46	1	2	14	3	8	72
1	0.73	19	36.64	37.1	0.71	1.48	1	2	13	6	8	70
1.02	0.72	19.865	38.29	38.76	0.72	1.51	2	2	11	9	7	68
1.04	0.71	20.751	39.95	40.42	0.74	1.53	2	2	11	12	6	67
1.06	0.7	21.659	41.6	42.08	0.75	1.53	2	2	10	12	7	66
1.08	0.69	22.588	43.26	43.75	0.76	1.56	2	2	9	15	7	64
1.1	0.68	23.54	44.92	45.41	0.77	1.54	2	3	9	14	9	64
1.12	0.68	24.513	46.57	47.07	0.77	1.57	2	3	8	15	10	62
1.14	0.68	25.508	48.23	48.73	0.78	1.6	2	3	8	15	12	60
1.16	0.67	26.525	49.89	50.39	0.79	1.6	2	3	7	15	14	59
1.18	0.67	27.564	51.54	52.05	0.8	1.61	2	3	7	14	16	58
1.2	0.67	28.625	52.98	53.5	0.8	1.62	2	3	7	13	18	57
1.22	0.68	29.709	53.7	54.22	0.81	1.65	2	3	7	11	21	56
1.24	0.7	30.815	54.05	54.58	0.82	1.66	1	4	7	9	22	57
1.26	0.71	31.943	54.41	54.93	0.82	1.67	1	4	7	8	23	58
1.28	0.73	33.094	54.76	55.29	0.83	1.68	1	4	7	5	24	60
1.3	0.75	34.268	55.11	55.65	0.83	1.69	0	4	7	3	24	61
1.32	0.76	35.465	55.46	56.01	0.84	1.7	0	4	7	3	23	63
1.34	0.78	36.684	55.82	56.36	0.85	1.74	0	4	7	3	22	64
1.36	0.79	37.926	56.17	56.72	0.85	1.74	0	4	7	3	20	66
1.38	0.81	39.191	56.52	57.08	0.86	1.74	0	4	7	2	18	69
1.4	0.82	40.48	56.87	57.43	0.87	1.75	0	4	7	2	16	71
1.42	0.84	41.791	57.07	57.63	0.87	1.79	0	4	6	3	13	73
1.44	0.86	43.126	57.21	57.78	0.88	1.8	0	4	6	2	12	76
1.46	0.87	44.484	57.36	57.93	0.89	1.8	0	4	7	1	10	79
1.48	0.89	45.866	57.5	58.08	0.89	1.83	0	4	6	2	7	80
1.5	0.91	47.271	57.64	58.23	0.9	1.83	0	4	7	1	6	82
1.52	0.93	48.699	57.79	58.38	0.91	1.84	0	3	7	0	5	84
1.54	0.94	50.152	57.93	58.53	0.92	1.87	0	3	7	0	5	85

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
1.56	0.96	51.628	58.07	58.68	0.92	1.9	0	3	7	1	5	84
1.58	0.98	53.128	58.22	58.83	0.93	1.89	0	3	8	0	5	85
1.6	1	54.651	58.36	58.98	0.94	1.9	0	2	8	0	4	86
1.62	1.01	56.199	58.5	59.13	0.95	1.91	0	2	8	0	4	86
1.64	1.03	57.771	58.65	59.28	0.95	1.97	0	2	8	1	4	86
1.66	1.05	59.366	58.79	59.43	0.96	1.97	0	1	8	0	4	87
1.68	1.07	60.986	58.94	59.58	0.97	2	0	1	8	1	3	87
1.7	1.08	62.63	59.08	59.73	0.98	2.02	0	1	8	1	3	87
1.72	1.1	64.299	59.22	59.88	0.99	2.01	0	1	8	0	3	88
1.74	1.12	65.992	59.39	60.04	0.99	2.04	0	1	8	1	2	87
1.76	1.14	67.709	59.55	60.21	1	2.03	0	1	8	0	2	88
1.78	1.15	69.451	59.71	60.38	1.01	2.06	0	1	8	1	2	88
1.8	1.17	71.218	59.88	60.55	1.02	2.05	0	1	8	0	2	89
1.82	1.19	73.009	60.04	60.72	1.02	2.08	0	1	8	0	2	89
1.84	1.2	74.825	60.2	60.88	1.03	2.12	0	1	8	1	2	88
1.86	1.22	76.665	60.37	61.05	1.04	2.12	0	1	8	0	2	89
1.88	1.24	78.531	60.53	61.22	1.05	2.15	0	1	8	1	2	88
1.9	1.25	80.421	60.69	61.39	1.06	2.15	0	0	8	0	2	89
1.92	1.27	82.337	60.86	61.56	1.07	2.18	0	0	8	1	3	88
1.94	1.29	84.277	61.02	61.72	1.07	2.17	0	0	8	0	2	89
1.96	1.3	86.243	61.18	61.89	1.08	2.18	0	0	8	0	2	89
1.98	1.32	88.234	61.34	62.06	1.09	2.19	0	0	8	0	2	89
2	1.34	90.25	61.51	62.23	1.1	2.2	0	0	8	0	2	90
2.02	1.35	92.291	61.67	62.4	1.11	2.25	0	0	7	1	2	89
2.04	1.37	94.358	61.83	62.56	1.11	2.28	0	0	7	1	3	88
2.06	1.39	96.45	62	62.73	1.12	2.3	0	0	7	1	3	88
2.08	1.4	98.568	62.16	62.9	1.13	2.3	0	0	7	1	2	89
2.1	1.42	100.711	62.32	63.07	1.14	2.32	0	0	7	1	2	89
2.12	1.43	102.88	62.49	63.24	1.15	2.34	0	0	7	1	2	90
2.14	1.45	105.075	62.65	63.4	1.16	2.37	0	0	7	1	3	89
2.16	1.47	107.295	62.81	63.57	1.16	2.38	0	0	7	1	3	89
2.18	1.48	109.541	62.97	63.74	1.17	2.4	0	0	7	1	3	89
2.2	1.5	111.814	63.14	63.91	1.18	2.41	0	0	7	1	3	89
2.22	1.51	114.111	63.3	64.07	1.19	2.4	0	0	7	1	2	90
2.24	1.53	116.435	63.46	64.24	1.2	2.41	0	0	7	1	2	90
2.26	1.55	118.785	63.63	64.41	1.21	2.45	0	0	6	1	2	89
2.28	1.56	121.161	63.79	64.58	1.22	2.46	0	0	6	1	2	90
2.3	1.58	123.564	63.95	64.75	1.22	2.46	0	0	6	1	2	91
2.32	1.6	125.992	64.12	64.91	1.23	2.48	0	0	6	1	2	91
2.34	1.61	128.447	64.28	65.08	1.24	2.53	0	0	6	1	2	90
2.36	1.63	130.928	64.44	65.25	1.25	2.52	0	0	6	1	2	91
2.38	1.64	133.435	64.66	65.48	1.26	2.54	0	0	6	1	2	91
2.4	1.65	135.969	64.91	65.73	1.27	2.56	0	0	6	1	2	91
2.42	1.67	138.529	65.16	65.98	1.27	2.6	0	0	6	1	2	90
2.44	1.68	141.116	65.41	66.23	1.28	2.62	0	0	6	1	2	90
2.46	1.7	143.73	65.65	66.48	1.29	2.64	0	0	6	1	2	90
2.48	1.71	146.37	65.9	66.73	1.3	2.63	0	0	6	1	3	90
2.5	1.72	149.037	66.14	66.98	1.31	2.66	0	0	6	2	3	90
2.52	1.74	151.73	66.39	67.23	1.32	2.65	0	0	6	1	2	91
2.54	1.75	154.451	66.64	67.48	1.32	2.67	0	0	6	1	2	91
2.56	1.76	157.198	66.88	67.73	1.33	2.71	0	0	5	2	3	90
2.58	1.78	159.972	67.13	67.98	1.34	2.74	0	0	5	2	3	90
2.6	1.79	162.773	67.37	68.23	1.35	2.73	0	0	5	1	2	91
2.62	1.8	165.601	67.62	68.48	1.36	2.77	0	0	5	2	3	89
2.64	1.82	168.457	67.86	68.73	1.37	2.76	0	0	5	1	3	90
2.66	1.83	171.339	68.11	68.98	1.37	2.79	0	0	5	2	3	90

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
2.68	1.84	174.248	68.36	69.23	1.38	2.78	0	0	5	1	3	91
2.7	1.86	177.185	68.6	69.48	1.39	2.81	0	0	5	1	3	90
2.72	1.87	180.149	68.85	69.73	1.4	2.83	0	0	5	2	3	90
2.74	1.88	183.141	69.09	69.98	1.41	2.82	0	0	5	1	3	91
2.76	1.9	186.159	69.34	70.23	1.41	2.87	0	0	5	2	3	90
2.78	1.91	189.205	69.58	70.48	1.42	2.86	0	0	5	1	3	91
2.8	1.92	192.279	69.83	70.73	1.43	2.92	0	0	5	2	3	90
2.82	1.94	195.38	70.08	70.98	1.44	2.9	0	0	5	1	3	91
2.84	1.95	198.509	70.32	71.23	1.45	2.92	0	0	5	1	3	91
2.86	1.96	201.665	70.57	71.48	1.46	2.96	0	0	5	1	3	90
2.88	1.98	204.849	70.81	71.73	1.46	2.98	0	0	5	1	3	90
2.9	1.99	208.061	71.11	72.03	1.47	2.96	0	0	5	1	3	91
2.92	2	211.3	71.49	72.41	1.48	2.96	0	0	5	1	3	91
2.94	2.01	214.567	71.87	72.8	1.49	2.98	0	0	5	1	3	91
2.96	2.02	217.863	72.25	73.18	1.5	3.01	0	0	5	1	3	91
2.98	2.03	221.186	72.63	73.56	1.5	3.03	0	0	4	1	3	91
3	2.04	224.536	73	73.94	1.51	3.07	0	0	4	2	4	90

SvS=Slow very Shallow; SS=Slow Shallow; SD=Slow Deep; FvS=Fast very Shallow; FS=Fast Shallow; FD=Fast Deep (for velocity and depth ranges refer to Birkhead 2010)

Table 3.11: Ecologically relevant hydraulic indicators at 8_Nzhelele

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.02	0.01	0	1.32	1.32	0	0	100	0	0	0	0	0
0.04	0.03	0	1.63	1.64	0	0.02	100	0	0	0	0	0
0.06	0.04	0.001	1.91	1.92	0.01	0.04	100	0	0	0	0	0
0.08	0.06	0.003	2.11	2.12	0.02	0.08	100	0	0	0	0	0
0.1	0.07	0.006	2.3	2.32	0.03	0.12	95	5	0	0	0	0
0.12	0.07	0.01	3.1	3.12	0.05	0.17	57	43	0	0	0	0
0.14	0.09	0.018	3.33	3.35	0.06	0.22	50	49	0	0	0	0
0.16	0.1	0.028	3.55	3.58	0.08	0.28	45	54	0	1	1	0
0.18	0.11	0.042	3.99	4.02	0.1	0.34	44	51	0	2	3	0
0.2	0.11	0.06	4.85	4.89	0.12	0.41	49	43	0	4	4	0
0.22	0.11	0.084	5.73	5.77	0.13	0.46	41	49	0	5	5	0
0.24	0.11	0.113	6.66	6.71	0.15	0.52	44	43	0	6	6	0
0.26	0.12	0.149	7.52	7.57	0.17	0.56	45	40	0	8	7	0
0.28	0.12	0.193	8.77	8.83	0.18	0.62	44	37	0	10	9	0
0.3	0.13	0.245	9.7	9.76	0.2	0.66	39	39	0	11	11	0
0.32	0.14	0.306	10	10.06	0.21	0.71	32	44	0	10	11	3
0.34	0.16	0.377	10.31	10.37	0.23	0.76	25	46	0	10	14	5
0.36	0.17	0.459	10.61	10.68	0.25	0.8	19	48	0	9	18	6
0.38	0.19	0.553	10.92	10.99	0.27	0.85	12	50	0	7	23	7
0.4	0.2	0.661	11.22	11.29	0.29	0.9	8	50	0	6	27	9
0.42	0.22	0.782	11.38	11.47	0.31	0.96	6	47	0	6	30	11
0.44	0.24	0.918	11.65	11.75	0.34	1.02	6	43	0	6	30	15
0.46	0.25	1.07	11.97	12.09	0.36	1.06	5	40	0	6	32	17
0.48	0.26	1.24	12.29	12.43	0.39	1.12	4	37	0	6	33	20
0.5	0.28	1.427	12.53	12.68	0.41	1.16	4	33	1	6	32	24
0.52	0.29	1.634	12.77	12.93	0.44	1.21	4	28	3	7	29	30
0.54	0.3	1.862	13.24	13.42	0.47	1.25	3	25	4	7	26	34
0.56	0.31	2.111	13.72	13.92	0.5	1.29	4	22	4	9	23	39
0.58	0.32	2.383	14.19	14.41	0.53	1.34	4	19	4	10	19	44
0.6	0.33	2.679	14.67	14.91	0.56	1.34	3	17	5	10	17	48
0.62	0.34	3	15.15	15.4	0.59	1.39	3	15	5	11	16	50

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.64	0.35	3.348	15.62	15.9	0.62	1.42	3	14	5	12	15	52
0.66	0.36	3.723	16.04	16.34	0.65	1.49	3	12	4	12	15	53
0.68	0.37	4.127	16.59	16.91	0.68	1.5	2	12	4	11	16	54
0.7	0.36	4.562	17.69	18.03	0.71	1.56	3	10	5	14	16	53
0.72	0.36	5.028	18.88	19.24	0.74	1.58	3	8	5	16	17	51
0.74	0.36	5.527	20.01	20.4	0.77	1.62	3	7	5	18	18	49
0.76	0.36	6.06	20.78	21.2	0.8	1.7	3	5	5	20	17	49
0.78	0.37	6.629	21.52	21.98	0.83	1.73	3	5	5	19	18	50
0.8	0.38	7.234	22.27	22.76	0.86	1.76	2	5	5	17	21	50
0.82	0.39	7.878	23.01	23.54	0.89	1.8	2	4	5	15	23	51
0.84	0.39	8.562	23.76	24.32	0.92	1.86	2	4	5	15	24	51
0.86	0.4	9.287	24.47	25.06	0.94	1.91	1	4	4	13	27	50
0.88	0.41	10.054	25.15	25.79	0.97	1.96	1	4	4	13	26	52
0.9	0.42	10.865	25.84	26.51	1	2.06	1	4	4	13	26	52
0.92	0.43	11.722	26.52	27.24	1.03	2.1	1	4	4	13	27	52
0.94	0.44	12.626	27.21	27.97	1.06	2.12	1	4	4	11	27	54
0.96	0.45	13.578	27.89	28.69	1.09	2.22	1	3	3	12	25	55
0.98	0.46	14.58	28.47	29.32	1.12	2.23	1	3	3	11	24	57
1	0.47	15.475	28.93	29.82	1.14	2.3	1	3	3	10	24	59
1.02	0.48	16.199	29.39	30.32	1.14	2.31	1	3	3	9	23	61
1.04	0.5	16.941	29.79	30.77	1.15	2.32	1	3	3	7	24	61
1.06	0.51	17.704	30.09	31.11	1.15	2.33	0	3	3	6	22	64
1.08	0.53	18.486	30.39	31.45	1.16	2.36	1	3	3	7	20	66
1.1	0.54	19.288	30.7	31.79	1.16	2.37	0	3	3	6	21	66
1.12	0.55	20.109	31	32.13	1.17	2.38	0	3	3	5	19	69
1.14	0.57	20.951	31.3	32.47	1.18	2.38	0	3	4	4	18	71
1.16	0.58	21.813	31.7	32.9	1.18	2.38	0	3	4	4	16	74
1.18	0.56	22.695	34.39	35.6	1.19	2.38	1	3	3	12	13	69
1.2	0.54	23.597	36.65	37.89	1.19	2.37	1	2	3	15	12	66
1.22	0.55	24.52	37.71	38.97	1.19	2.4	1	2	4	17	9	67
1.24	0.55	25.464	38.64	39.91	1.19	2.43	1	2	4	18	10	65
1.26	0.56	26.428	39.56	40.85	1.2	2.44	1	2	4	15	13	65
1.28	0.57	27.414	40.48	41.8	1.2	2.46	1	2	4	13	16	64
1.3	0.57	28.42	41.4	42.74	1.2	2.43	1	2	4	11	16	65
1.32	0.58	29.448	42.33	43.68	1.2	2.41	1	2	4	10	17	65
1.34	0.59	30.497	43.25	44.63	1.2	2.44	1	2	4	11	18	64
1.36	0.6	31.567	44.17	45.57	1.2	2.42	1	2	4	9	20	64
1.38	0.6	32.659	45.1	46.51	1.2	2.41	1	2	4	9	22	63
1.4	0.62	33.773	45.6	47.03	1.2	2.43	1	2	4	8	22	63
1.42	0.63	34.909	45.92	47.37	1.2	2.45	1	2	4	8	22	63
1.44	0.65	36.066	46.24	47.71	1.2	2.42	0	2	4	5	24	64
1.46	0.66	37.245	46.57	48.06	1.21	2.49	0	2	4	6	23	64
1.48	0.68	38.447	46.75	48.26	1.21	2.44	0	2	4	4	20	70
1.5	0.7	39.671	46.83	48.35	1.21	2.46	0	2	4	2	19	72
1.52	0.72	40.917	46.86	48.4	1.22	2.48	0	2	4	2	18	74
1.54	0.74	42.185	46.89	48.45	1.22	2.47	0	2	4	1	14	78
1.56	0.76	43.477	46.92	48.5	1.22	2.47	0	2	4	0	14	80
1.58	0.78	44.791	46.95	48.55	1.23	2.49	0	2	4	0	12	81
1.6	0.8	46.127	46.98	48.6	1.23	2.51	0	2	4	1	10	82
1.62	0.82	47.487	47.01	48.65	1.24	2.5	0	2	4	1	8	85
1.64	0.84	48.87	47.05	48.71	1.24	2.51	0	2	5	1	6	86
1.66	0.85	50.276	47.08	48.76	1.25	2.52	0	2	5	0	6	87
1.68	0.87	51.705	47.11	48.81	1.26	2.54	0	2	5	0	4	89
1.7	0.89	53.157	47.14	48.86	1.26	2.58	0	1	5	1	4	89
1.72	0.91	54.633	47.17	48.91	1.27	2.58	0	1	5	1	3	90
1.74	0.93	56.133	47.2	48.96	1.28	2.61	0	1	5	1	2	91

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
1.76	0.95	57.656	47.23	49.01	1.28	2.58	0	1	5	0	1	93
1.78	0.97	59.203	47.26	49.06	1.29	2.6	0	1	5	0	1	93
1.8	0.99	60.774	47.29	49.11	1.3	2.61	0	1	5	0	1	93
1.82	1.01	62.369	47.32	49.16	1.3	2.66	0	1	5	1	1	93
1.84	1.03	63.988	47.35	49.21	1.31	2.67	0	0	5	1	0	93
1.86	1.05	65.632	47.38	49.26	1.32	2.69	0	0	6	1	0	93
1.88	1.07	67.299	47.42	49.32	1.33	2.7	0	0	6	0	0	94
1.9	1.09	68.991	47.45	49.37	1.34	2.72	0	0	6	0	0	94
1.92	1.11	70.708	47.48	49.42	1.35	2.73	0	0	6	0	0	94
1.94	1.13	72.449	47.51	49.47	1.35	2.76	0	0	5	1	0	93
1.96	1.14	74.214	47.59	49.56	1.36	2.76	0	0	6	0	0	94
1.98	1.16	76.005	47.67	49.66	1.37	2.81	0	0	5	1	0	94
2	1.18	77.82	47.76	49.75	1.38	2.79	0	0	6	0	0	94
2.02	1.2	79.661	47.84	49.84	1.39	2.83	0	0	5	1	0	94
2.04	1.22	81.526	47.92	49.94	1.4	2.83	0	0	5	0	0	94
2.06	1.23	83.417	48	50.03	1.41	2.85	0	0	5	0	0	94
2.08	1.25	85.333	48.08	50.12	1.42	2.9	0	0	5	1	1	93
2.1	1.27	87.274	48.17	50.22	1.43	2.88	0	0	5	0	1	94
2.12	1.29	89.241	48.25	50.31	1.44	2.93	0	0	5	1	1	93
2.14	1.31	91.233	48.33	50.41	1.45	2.91	0	0	5	0	1	94
2.16	1.32	93.251	48.41	50.5	1.46	2.95	0	0	5	1	1	93
2.18	1.34	95.295	48.49	50.59	1.47	2.96	0	0	5	0	1	94
2.2	1.36	97.365	48.57	50.69	1.48	3.01	0	0	5	1	1	93
2.22	1.38	99.46	48.66	50.78	1.49	3.03	0	0	5	1	1	93
2.24	1.39	101.582	48.74	50.87	1.5	3.02	0	0	5	0	1	94
2.26	1.41	103.729	48.82	50.97	1.51	3.06	0	0	5	1	1	93
2.28	1.43	105.903	48.9	51.06	1.52	3.05	0	0	5	0	1	94
2.3	1.45	108.103	48.98	51.15	1.53	3.1	0	0	5	1	1	93
2.32	1.46	110.33	49.07	51.25	1.54	3.08	0	0	5	1	1	93
2.34	1.48	112.583	49.15	51.34	1.55	3.14	0	0	5	1	2	93
2.36	1.5	114.862	49.23	51.43	1.56	3.16	0	0	4	1	2	93
2.38	1.52	117.168	49.31	51.53	1.57	3.16	0	0	5	1	1	94
2.4	1.53	119.501	49.39	51.62	1.58	3.21	0	0	4	1	2	93
2.42	1.55	121.861	49.48	51.72	1.59	3.21	0	0	4	1	1	94
2.44	1.57	124.247	49.56	51.81	1.6	3.23	0	0	4	1	1	94
2.46	1.59	126.661	49.64	51.9	1.61	3.26	0	0	4	1	1	94
2.48	1.6	129.101	49.72	52	1.62	3.28	0	0	4	1	1	94
2.5	1.62	131.569	49.8	52.09	1.63	3.3	0	0	4	1	1	94
2.52	1.64	134.064	49.89	52.19	1.64	3.3	0	0	4	1	1	94
2.54	1.66	136.586	49.97	52.28	1.65	3.32	0	0	4	1	1	94
2.56	1.67	139.136	50.05	52.37	1.66	3.35	0	0	4	1	1	94
2.58	1.69	141.713	50.13	52.47	1.67	3.37	0	0	4	1	1	94
2.6	1.71	144.318	50.22	52.56	1.68	3.39	0	0	4	1	1	94
2.62	1.72	146.95	50.3	52.66	1.69	3.41	0	0	4	1	1	94
2.64	1.74	149.61	50.38	52.75	1.7	3.45	0	0	4	1	1	94
2.66	1.76	152.298	50.46	52.84	1.72	3.47	0	0	4	1	1	94
2.68	1.78	155.014	50.55	52.94	1.73	3.49	0	0	4	1	1	94
2.7	1.79	157.758	50.63	53.03	1.74	3.51	0	0	4	1	1	94
2.72	1.81	160.53	50.71	53.13	1.75	3.52	0	0	4	1	1	94
2.74	1.83	163.33	50.79	53.22	1.76	3.54	0	0	4	1	1	94
2.76	1.84	166.158	50.88	53.31	1.77	3.56	0	0	4	1	1	94
2.78	1.85	169.015	51.28	53.72	1.78	3.6	0	0	4	1	2	94
2.8	1.85	171.9	51.94	54.39	1.79	3.62	0	0	4	2	2	92
2.82	1.84	174.813	52.61	55.06	1.8	3.68	0	0	4	3	3	91
2.84	1.84	177.755	53.28	55.73	1.81	3.7	0	0	4	3	3	90
2.86	1.84	180.726	53.94	56.4	1.82	3.72	0	0	4	3	4	89

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
2.88	1.83	183.725	54.72	57.18	1.83	3.75	0	0	3	4	4	88
2.9	1.81	186.753	55.82	58.28	1.84	3.76	0	0	3	5	5	86
2.92	1.8	189.81	56.92	59.39	1.85	3.8	0	0	3	5	6	85
2.94	1.74	192.895	59.38	61.85	1.86	3.79	0	0	3	7	8	81
2.96	1.69	196.01	62.08	64.56	1.87	3.8	0	0	3	9	10	77
2.98	1.64	199.154	64.79	67.27	1.88	3.74	0	0	3	9	10	77
3	1.59	202.327	67.49	69.98	1.88	3.76	0	1	3	11	12	74
3.02	1.56	205.529	69.86	72.35	1.89	3.8	0	1	3	11	13	72
3.04	1.53	208.761	72.14	74.63	1.9	3.8	0	1	3	12	14	70
3.06	1.5	212.022	74.42	76.92	1.9	3.83	0	1	3	13	16	68
3.08	1.47	215.312	76.7	79.2	1.9	3.85	1	1	2	13	17	66
3.1	1.45	218.632	78.99	81.49	1.91	3.87	1	1	2	14	18	65
3.12	1.43	221.981	81.27	83.78	1.91	3.9	1	1	2	14	18	64
3.14	1.43	225.36	82.38	84.89	1.91	3.9	1	1	2	14	18	64
3.16	1.44	228.769	83.09	85.6	1.91	3.86	0	1	2	12	18	66
3.18	1.46	232.208	83.31	85.83	1.92	3.89	0	1	2	11	18	67
3.2	1.47	235.677	83.54	86.06	1.92	3.86	0	1	2	9	17	70
3.22	1.49	239.175	83.77	86.29	1.92	3.86	0	1	2	8	16	72
3.24	1.5	242.704	83.99	86.52	1.92	3.92	0	1	2	7	16	73
3.26	1.52	246.263	84.22	86.75	1.93	3.88	0	1	2	5	15	76
3.28	1.53	249.852	84.44	86.99	1.93	3.91	0	1	2	5	15	77
3.3	1.55	253.471	84.67	87.22	1.93	3.96	0	1	2	4	14	79
3.32	1.57	257.12	84.9	87.45	1.93	3.96	0	1	2	3	13	81
3.34	1.58	260.8	85.12	87.68	1.94	3.95	0	1	2	2	12	83
3.36	1.6	264.511	85.35	87.91	1.94	3.97	0	1	2	1	11	84
3.38	1.61	268.252	85.58	88.14	1.94	3.99	0	1	2	1	11	85
3.4	1.63	272.023	85.8	88.37	1.95	3.96	0	1	3	1	10	86
3.42	1.65	275.825	86.03	88.6	1.95	3.97	0	1	3	1	8	87
3.44	1.66	279.658	86.26	88.83	1.95	4.01	0	1	3	1	8	87
3.46	1.68	283.522	86.48	89.06	1.96	4	0	1	3	1	7	88
3.48	1.69	287.417	86.71	89.29	1.96	3.97	0	1	3	1	6	89
3.5	1.71	291.342	86.93	89.52	1.96	4	0	1	3	1	6	90
3.52	1.72	295.299	87.16	89.75	1.97	4.02	0	1	3	1	5	90
3.54	1.74	299.287	87.39	89.98	1.97	3.99	0	1	3	1	4	92
3.56	1.75	303.306	87.61	90.21	1.97	3.99	0	0	3	1	3	92
3.58	1.77	307.356	87.84	90.45	1.98	4.04	0	0	3	1	3	92
3.6	1.79	311.437	88.07	90.68	1.98	4	0	0	3	1	3	93
3.62	1.8	315.55	88.29	90.91	1.98	4.01	0	0	3	1	2	94
3.64	1.82	319.695	88.52	91.14	1.99	4.03	0	0	3	1	2	93
3.66	1.83	323.87	88.75	91.37	1.99	4.05	0	0	3	1	2	93
3.68	1.85	328.078	88.97	91.6	2	4.02	0	0	3	1	2	94
3.7	1.86	332.317	89.2	91.83	2	4.03	0	0	3	1	2	94
3.72	1.88	336.587	89.42	92.06	2.01	4.07	0	0	3	1	2	93
3.74	1.89	340.89	89.55	92.19	2.01	4.08	0	0	3	1	2	93
3.76	1.91	345.224	89.65	92.3	2.01	4.08	0	0	3	1	2	93
3.78	1.93	349.59	89.75	92.41	2.02	4.08	0	0	3	1	2	94
3.8	1.95	353.989	89.85	92.52	2.02	4.09	0	0	3	1	2	94
3.82	1.97	358.419	89.96	92.63	2.03	4.1	0	0	3	1	2	94
3.84	1.98	362.881	90.06	92.74	2.03	4.1	0	0	3	1	2	94
3.86	2	367.376	90.16	92.85	2.04	4.12	0	0	3	1	2	94
3.88	2.02	371.902	90.27	92.96	2.04	4.13	0	0	3	1	2	94
3.9	2.04	376.461	90.37	93.08	2.05	4.15	0	0	3	1	2	94
3.92	2.05	381.053	90.47	93.19	2.05	4.17	0	0	3	1	2	94
3.94	2.07	385.676	90.58	93.3	2.06	4.18	0	0	3	0	1	95
3.96	2.09	390.333	90.68	93.41	2.06	4.2	0	0	3	0	1	95
3.98	2.11	395.022	90.78	93.52	2.07	4.21	0	0	3	0	1	95

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
4	2.12	399.743	90.88	93.63	2.07	4.22	0	0	3	0	1	95
4.02	2.14	404.497	90.99	93.74	2.08	4.24	0	0	3	0	1	95
4.04	2.16	409.284	91.09	93.85	2.08	4.21	0	0	3	0	0	96
4.06	2.18	414.104	91.19	93.96	2.09	4.2	0	0	3	0	0	96
4.08	2.2	418.956	91.3	94.07	2.09	4.21	0	0	3	0	0	96
4.1	2.21	423.842	91.4	94.18	2.1	4.22	0	0	3	0	0	96
4.12	2.23	428.76	91.5	94.29	2.1	4.22	0	0	3	0	0	96
4.14	2.25	433.712	91.61	94.41	2.11	4.23	0	0	3	0	0	96
4.16	2.26	438.697	91.71	94.52	2.11	4.24	0	0	3	0	0	96
4.18	2.28	443.715	91.81	94.63	2.12	4.25	0	0	3	0	0	96
4.2	2.3	448.766	91.91	94.74	2.12	4.23	0	0	3	0	0	96
4.22	2.32	453.85	92.02	94.85	2.13	4.25	0	0	3	0	0	96
4.24	2.33	458.968	92.12	94.96	2.13	4.26	0	0	3	0	0	96
4.26	2.35	464.119	92.22	95.07	2.14	4.27	0	0	3	0	0	97
4.28	2.37	469.304	92.33	95.18	2.15	4.28	0	0	3	0	0	97
4.3	2.39	474.522	92.43	95.29	2.15	4.3	0	0	3	0	0	97
4.32	2.4	479.774	92.53	95.4	2.16	4.36	0	0	3	0	1	96
4.34	2.42	485.059	92.63	95.51	2.16	4.41	0	0	3	1	1	95
4.36	2.44	490.379	92.74	95.62	2.17	4.44	0	0	3	1	1	95
4.38	2.46	495.732	92.84	95.74	2.17	4.45	0	0	3	1	1	95
4.4	2.47	501.119	92.94	95.85	2.18	4.48	0	0	3	1	1	95
4.42	2.49	506.539	93.05	95.96	2.19	4.5	0	0	3	1	1	95
4.44	2.51	511.994	93.15	96.07	2.19	4.51	0	0	3	1	1	95
4.46	2.52	517.483	93.25	96.18	2.2	4.52	0	0	3	1	1	95
4.48	2.54	523.006	93.36	96.29	2.2	4.53	0	0	3	1	1	95
4.5	2.56	528.563	93.47	96.41	2.21	4.53	0	0	3	1	1	95
4.52	2.57	534.154	93.63	96.58	2.22	4.54	0	0	3	1	1	95
4.54	2.59	539.78	93.78	96.74	2.22	4.5	0	0	3	0	1	96
4.56	2.61	545.44	93.94	96.9	2.23	4.5	0	0	3	0	1	96
4.58	2.62	551.134	94.09	97.06	2.23	4.55	0	0	3	1	1	95
4.6	2.64	556.863	94.25	97.22	2.24	4.56	0	0	3	1	1	95
4.62	2.65	562.626	94.4	97.38	2.25	4.57	0	0	3	1	1	95
4.64	2.67	568.424	94.55	97.54	2.25	4.53	0	0	3	0	1	96
4.66	2.68	574.256	94.71	97.7	2.26	4.54	0	0	3	0	1	96
4.68	2.7	580.124	94.86	97.86	2.26	4.51	0	0	3	0	1	96
4.7	2.72	586.025	95.02	98.02	2.27	4.57	0	0	3	1	1	95
4.72	2.73	591.962	95.17	98.18	2.28	4.59	0	0	3	1	1	95
4.74	2.75	597.934	95.33	98.34	2.28	4.62	0	0	3	1	1	95
4.76	2.76	603.94	95.48	98.5	2.29	4.59	0	0	3	0	1	96
4.78	2.78	609.981	95.63	98.67	2.3	4.62	0	0	3	0	1	96
4.8	2.79	616.058	95.79	98.83	2.3	4.68	0	0	3	1	1	95
4.82	2.8	622.169	96.09	99.14	2.31	4.66	0	0	3	0	1	96
4.84	2.81	628.316	96.5	99.54	2.31	4.69	0	0	3	1	1	95
4.86	2.82	634.498	96.9	99.95	2.32	4.7	0	0	3	1	1	95
4.88	2.83	640.715	97.31	100.36	2.33	4.7	0	0	3	1	1	95
4.9	2.84	646.967	97.72	100.77	2.33	4.72	0	0	3	1	1	95
4.92	2.85	653.255	98.12	101.18	2.34	4.73	0	0	3	1	2	94
4.94	2.85	659.578	98.53	101.58	2.35	4.79	0	0	3	1	2	93
4.96	2.86	665.937	98.93	101.99	2.35	4.79	0	0	3	1	2	93
4.98	2.87	672.331	99.34	102.4	2.36	4.79	0	0	3	1	2	93
5	2.88	678.761	99.75	102.81	2.36	4.8	0	0	3	1	3	93

SvS=Slow very Shallow; SS=Slow Shallow; SD=Slow Deep; FvS=Fast very Shallow; FS=Fast Shallow; FD=Fast Deep (for velocity and depth ranges refer to Birkhead 2010)

Table 3.12: Ecologically relevant hydraulic indicators at 9_Ṅwaneḍi

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.02	0.01	0	0.46	0.46	0.03	0.12	100	0	0	0	0	0
0.04	0.02	0.001	0.71	0.72	0.07	0.23	100	0	0	0	0	0
0.06	0.04	0.004	0.82	0.84	0.11	0.37	94	0	0	6	0	0
0.08	0.05	0.008	0.93	0.96	0.17	0.54	87	0	0	13	0	0
0.1	0.04	0.016	2.18	2.21	0.19	0.59	80	1	0	19	0	0
0.12	0.05	0.027	2.57	2.61	0.21	0.64	64	13	0	19	4	0
0.14	0.07	0.041	2.73	2.78	0.23	0.71	54	19	0	20	7	0
0.16	0.08	0.06	2.89	2.95	0.25	0.79	47	19	0	25	10	0
0.18	0.1	0.085	3.05	3.11	0.28	0.89	39	19	0	28	14	0
0.2	0.11	0.114	3.23	3.3	0.32	0.97	18	35	0	16	31	0
0.22	0.13	0.15	3.41	3.48	0.35	1.07	12	36	0	13	39	0
0.24	0.14	0.192	3.59	3.67	0.39	1.16	10	33	0	13	44	0
0.26	0.15	0.242	3.7	3.79	0.42	1.26	8	30	0	13	49	0
0.28	0.17	0.299	3.8	3.9	0.46	1.36	7	28	0	12	53	0
0.3	0.18	0.364	3.93	4.03	0.5	1.48	6	26	0	12	55	1
0.32	0.2	0.438	4.07	4.19	0.55	1.58	4	25	0	11	52	8
0.34	0.21	0.521	4.22	4.34	0.59	1.68	4	23	0	11	50	12
0.36	0.22	0.613	4.36	4.49	0.63	1.77	4	21	0	12	49	14
0.38	0.24	0.716	4.51	4.64	0.68	1.87	4	19	0	12	45	20
0.4	0.25	0.829	4.65	4.8	0.72	1.96	3	18	0	12	32	35
0.42	0.26	0.953	4.8	4.95	0.77	2.03	3	16	0	12	27	42
0.44	0.27	1.088	4.94	5.1	0.81	2.06	2	15	0	12	25	46
0.46	0.28	1.236	5.08	5.25	0.86	2.07	2	13	0	12	25	48
0.48	0.3	1.396	5.23	5.4	0.9	2.09	2	12	0	12	24	50
0.5	0.31	1.568	5.37	5.56	0.95	2.14	2	11	0	11	23	53
0.52	0.32	1.754	5.52	5.71	1	2.18	1	9	1	11	23	55
0.54	0.33	1.954	5.66	5.86	1.04	2.21	1	8	1	11	22	58
0.56	0.34	2.168	5.8	6.01	1.09	2.27	1	7	1	10	22	59
0.58	0.35	2.397	5.95	6.16	1.14	2.36	1	6	2	10	22	59
0.6	0.37	2.641	6.09	6.32	1.19	2.43	1	4	2	10	22	61
0.62	0.37	2.9	6.29	6.52	1.23	2.51	1	3	3	10	22	61
0.64	0.37	3.128	6.74	6.97	1.26	2.57	1	3	3	15	20	59
0.66	0.35	3.358	7.48	7.73	1.28	2.61	1	3	2	20	19	55
0.68	0.34	3.596	8.22	8.48	1.29	2.64	2	2	2	25	17	52
0.7	0.33	3.842	8.97	9.24	1.3	2.63	2	2	2	30	15	49
0.72	0.32	4.097	9.71	9.99	1.31	2.61	2	2	2	32	15	47
0.74	0.33	4.36	9.96	10.24	1.31	2.64	2	2	2	29	17	47
0.76	0.35	4.632	10.12	10.41	1.31	2.63	2	2	2	24	22	48
0.78	0.36	4.913	10.28	10.58	1.31	2.67	1	3	2	19	27	48
0.8	0.38	5.201	10.44	10.74	1.32	2.65	1	3	2	13	31	49
0.82	0.39	5.499	10.6	10.91	1.32	2.68	1	3	2	9	36	49
0.84	0.41	5.804	10.76	11.08	1.33	2.68	0	3	2	6	38	50
0.86	0.42	6.119	10.92	11.24	1.33	2.72	0	3	2	7	37	50
0.88	0.43	6.442	11.07	11.41	1.34	2.7	0	3	2	5	38	51
0.9	0.45	6.773	11.23	11.58	1.35	2.71	0	3	2	6	36	52
0.92	0.46	7.113	11.37	11.73	1.35	2.72	0	3	2	6	34	54
0.94	0.48	7.461	11.46	11.83	1.36	2.75	0	3	2	6	31	57
0.96	0.49	7.819	11.54	11.94	1.37	2.78	0	3	2	5	28	61
0.98	0.51	8.184	11.63	12.04	1.38	2.77	0	3	3	4	23	67
1	0.53	8.559	11.71	12.14	1.39	2.82	0	3	3	4	19	71
1.02	0.54	8.942	11.8	12.24	1.39	2.85	0	3	3	4	16	75
1.04	0.56	9.333	11.89	12.35	1.4	2.85	0	3	3	3	14	78
1.06	0.58	9.734	11.97	12.45	1.41	2.87	0	3	3	3	12	79
1.08	0.59	10.143	12.06	12.55	1.42	2.91	0	2	3	4	11	81

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
1.1	0.61	10.56	12.14	12.66	1.43	2.89	0	2	3	3	10	82
1.12	0.62	10.987	12.23	12.76	1.44	2.9	0	2	3	3	9	83
1.14	0.64	11.422	12.32	12.86	1.45	2.97	0	2	3	3	8	83
1.16	0.65	11.865	12.4	12.96	1.46	2.96	0	2	3	2	8	84
1.18	0.67	12.318	12.49	13.07	1.47	2.98	0	2	3	3	8	85
1.2	0.68	12.779	12.57	13.17	1.48	3.03	0	1	4	4	7	84
1.22	0.7	13.249	12.66	13.27	1.5	3.04	0	1	4	3	6	86
1.24	0.71	13.727	12.75	13.38	1.51	3.04	0	1	4	2	6	87
1.26	0.73	14.215	12.83	13.48	1.52	3.09	0	1	4	3	6	86
1.28	0.75	14.711	12.92	13.58	1.53	3.12	0	1	4	3	6	86
1.3	0.76	15.216	13.01	13.68	1.54	3.1	0	1	4	2	6	87
1.32	0.78	15.73	13.09	13.79	1.55	3.17	0	1	4	2	6	86
1.34	0.79	16.252	13.21	13.92	1.56	3.17	0	1	4	2	6	87
1.36	0.8	16.783	13.34	14.07	1.57	3.18	0	1	4	3	5	87
1.38	0.81	17.323	13.47	14.21	1.58	3.25	0	1	4	4	6	85
1.4	0.82	17.872	13.6	14.36	1.59	3.24	0	1	4	3	6	86
1.42	0.84	18.43	13.74	14.51	1.6	3.28	0	1	4	5	5	86
1.44	0.85	18.997	13.87	14.66	1.61	3.3	0	1	4	5	6	85
1.46	0.7	19.572	17.22	18.03	1.62	3.25	1	0	3	21	5	69
1.48	0.7	20.156	17.83	18.66	1.62	3.26	1	0	3	23	5	68
1.5	0.69	20.749	18.45	19.29	1.62	3.3	1	0	3	26	5	65
1.52	0.69	21.351	19.06	19.92	1.62	3.29	1	0	3	25	6	64
1.54	0.69	21.962	19.67	20.55	1.62	3.3	1	0	3	27	6	63
1.56	0.69	22.582	20.28	21.17	1.62	3.27	1	1	3	15	21	60
1.58	0.69	23.21	20.89	21.8	1.62	3.25	1	1	3	14	23	59
1.6	0.69	23.848	21.5	22.43	1.61	3.24	1	1	3	13	24	59
1.62	0.69	24.494	22.11	23.06	1.61	3.28	1	1	2	13	26	57
1.64	0.69	25.149	22.75	23.71	1.61	3.25	1	1	2	12	27	56
1.66	0.69	25.814	23.44	24.42	1.6	3.25	1	2	2	12	28	55
1.68	0.69	26.487	24.14	25.14	1.6	3.21	1	2	2	13	25	57
1.7	0.69	27.169	24.83	25.85	1.59	3.18	1	2	2	13	25	58
1.72	0.69	27.86	25.52	26.55	1.58	3.21	1	2	2	13	25	57
1.74	0.69	28.56	26.1	27.16	1.58	3.2	1	2	2	13	25	58
1.76	0.7	29.268	26.71	27.78	1.57	3.15	1	2	2	11	26	59
1.78	0.7	29.986	27.32	28.4	1.56	3.18	1	2	2	12	25	58
1.8	0.71	30.713	27.93	29.02	1.56	3.13	0	2	2	10	27	59
1.82	0.72	31.449	28.11	29.21	1.55	3.1	0	2	2	9	22	65
1.84	0.74	32.193	28.2	29.31	1.54	3.1	0	2	2	8	21	66
1.86	0.76	32.947	28.3	29.42	1.54	3.09	0	2	2	7	20	68
1.88	0.77	33.71	28.4	29.52	1.53	3.05	0	2	2	5	19	72
1.9	0.79	34.481	28.49	29.63	1.53	3.09	0	2	2	3	20	72
1.92	0.81	35.262	28.59	29.73	1.52	3.08	0	2	2	1	19	75
1.94	0.83	36.052	28.69	29.84	1.52	3.1	0	2	2	1	18	76
1.96	0.84	36.85	28.78	29.95	1.52	3.07	0	2	3	1	16	79
1.98	0.86	37.658	28.88	30.05	1.52	3.08	0	2	3	1	14	80
2	0.88	38.475	28.98	30.16	1.51	3.06	0	2	3	1	13	81
2.02	0.89	39.301	29.07	30.26	1.51	3.04	0	2	3	1	11	83
2.04	0.91	40.135	29.17	30.37	1.51	3.03	0	2	3	1	9	86
2.06	0.93	40.979	29.27	30.48	1.51	3.07	0	1	3	1	8	86
2.08	0.95	41.832	29.36	30.58	1.51	3.03	0	1	4	1	5	89
2.1	0.96	42.694	29.46	30.69	1.51	3.06	0	1	4	1	5	89
2.12	0.98	43.565	29.56	30.79	1.51	3.07	0	1	4	1	4	89
2.14	1	44.445	29.65	30.9	1.5	3.05	0	1	4	1	4	90
2.16	1.01	45.334	29.75	31.01	1.5	3.07	0	1	4	1	4	90
2.18	1.03	46.232	29.85	31.11	1.5	3.05	0	1	4	1	4	91
2.2	1.05	47.139	29.94	31.22	1.5	3.05	0	1	4	1	4	90

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
2.22	1.06	48.056	30.04	31.32	1.51	3.02	0	1	4	1	3	91
2.24	1.08	48.981	30.14	31.43	1.51	3.03	0	1	4	1	3	91
2.26	1.1	49.916	30.23	31.54	1.51	3.06	0	1	4	1	3	90
2.28	1.11	50.859	30.33	31.64	1.51	3.06	0	1	4	1	3	90
2.3	1.13	51.812	30.43	31.75	1.51	3.06	0	0	4	1	3	91
2.32	1.14	52.774	30.54	31.87	1.51	3.07	0	0	4	1	3	91
2.34	1.16	53.745	30.66	31.99	1.51	3.05	0	0	4	1	3	92
2.36	1.18	54.725	30.77	32.11	1.51	3.06	0	0	4	1	3	92
2.38	1.19	55.714	30.88	32.23	1.51	3.1	0	0	4	1	3	91
2.4	1.21	56.712	30.99	32.35	1.52	3.11	0	0	4	2	3	91
2.42	1.22	57.719	31.1	32.47	1.52	3.11	0	0	4	2	3	91
2.44	1.24	58.736	31.21	32.59	1.52	3.05	0	0	5	1	2	92
2.46	1.25	59.762	31.32	32.71	1.52	3.08	0	0	4	2	3	90
2.48	1.27	60.796	31.45	32.85	1.52	3.08	0	0	4	2	3	90
2.5	1.28	61.84	31.67	33.07	1.53	3.08	0	0	4	2	3	90
2.52	1.29	62.894	31.88	33.29	1.53	3.05	0	0	4	2	3	90
2.54	1.3	63.956	32.1	33.51	1.53	3.09	0	0	4	2	4	89
2.56	1.31	65.027	32.31	33.72	1.53	3.1	0	0	4	3	3	89
2.58	1.33	66.108	32.53	33.94	1.53	3.06	0	0	4	2	4	89
2.6	1.33	67.198	33	34.42	1.54	3.08	0	0	4	2	4	89
2.62	1.33	68.297	33.52	34.94	1.54	3.08	0	0	4	3	5	88
2.64	1.33	69.405	34.04	35.46	1.54	3.09	0	0	4	4	4	87
2.66	1.32	70.522	34.78	36.21	1.54	3.12	0	0	4	5	6	84
2.68	1.3	71.649	35.87	37.3	1.54	3.09	0	0	4	6	7	83
2.7	1.28	72.785	36.96	38.4	1.54	3.1	0	1	4	7	8	81
2.72	1.26	73.93	38.05	39.49	1.54	3.1	0	1	4	8	8	79
2.74	1.25	75.084	38.88	40.33	1.54	3.09	0	1	4	8	9	78
2.76	1.25	76.247	39.67	41.12	1.54	3.1	0	1	4	10	11	75
2.78	1.24	77.42	40.46	41.91	1.54	3.07	0	1	4	9	11	75
2.8	1.24	78.602	41.24	42.7	1.54	3.07	0	1	4	10	11	74
2.82	1.24	79.793	42.03	43.49	1.53	3.1	0	1	3	10	12	73
2.84	1.23	80.993	42.81	44.28	1.53	3.09	0	1	3	10	13	72
2.86	1.23	82.202	43.6	45.07	1.53	3.05	0	1	3	9	13	73
2.88	1.23	83.421	44.38	45.86	1.53	3.04	0	1	3	8	14	73
2.9	1.23	84.649	45.17	46.65	1.53	3.06	0	1	3	9	14	72
2.92	1.23	85.886	45.95	47.44	1.52	3.06	0	1	3	8	14	73
2.94	1.23	87.133	46.74	48.23	1.52	3.06	0	1	3	8	15	73
2.96	1.23	88.389	47.53	49.03	1.52	3.05	0	1	3	8	15	72
2.98	1.23	89.654	48.31	49.82	1.51	3.04	0	1	3	8	15	72
3	1.23	90.928	49.1	50.61	1.51	3.05	0	1	3	7	15	73
3.02	1.23	92.211	49.88	51.4	1.51	3.03	0	1	3	7	15	73
3.04	1.23	93.504	50.6	52.13	1.5	3.08	0	1	3	7	16	72
3.06	1.23	94.806	51.3	52.84	1.5	3.06	0	1	3	7	16	72
3.08	1.24	96.117	52	53.54	1.5	3.06	0	1	3	7	15	73
3.1	1.24	97.438	52.7	54.25	1.49	3.03	0	1	3	6	14	75
3.12	1.24	98.768	53.41	54.96	1.49	3.02	0	1	3	6	14	76
3.14	1.25	100.107	54.11	55.67	1.48	3.04	0	1	3	7	13	75
3.16	1.25	101.455	54.81	56.38	1.48	3.01	0	1	3	7	13	75
3.18	1.25	102.813	55.51	57.09	1.48	2.97	0	1	3	6	12	77
3.2	1.26	104.18	56.21	57.8	1.47	3	0	1	3	6	13	76
3.22	1.26	105.556	56.91	58.51	1.47	2.99	0	1	3	6	12	77
3.24	1.27	106.942	57.61	59.22	1.46	2.95	0	1	3	5	12	78
3.26	1.27	108.337	58.32	59.93	1.46	2.97	0	1	3	6	12	77
3.28	1.28	109.741	59.02	60.64	1.46	2.94	0	1	4	5	11	79
3.3	1.28	111.155	59.72	61.34	1.45	2.95	0	1	4	6	11	78
3.32	1.29	112.578	60.42	62.05	1.45	2.95	0	1	4	6	11	78

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
3.34	1.29	114.01	61.12	62.76	1.44	2.91	0	1	4	5	11	79
3.36	1.3	115.451	61.82	63.47	1.44	2.91	0	1	4	5	11	79
3.38	1.3	116.902	62.52	64.18	1.44	2.88	0	1	4	5	10	80
3.4	1.31	118.362	63.22	64.89	1.43	2.9	0	1	4	5	11	79
3.42	1.31	119.832	63.93	65.6	1.43	2.85	0	1	4	5	10	80
3.44	1.32	121.311	64.63	66.31	1.42	2.87	0	1	4	5	10	80
3.46	1.32	122.799	65.33	67.02	1.42	2.83	0	1	4	5	10	81
3.48	1.33	124.297	66.03	67.73	1.42	2.85	0	1	4	5	10	80
3.5	1.34	125.804	66.48	68.18	1.41	2.85	0	1	4	4	9	81
3.52	1.35	127.32	66.86	68.57	1.41	2.85	0	1	4	4	9	81
3.54	1.37	128.845	67.24	68.95	1.4	2.84	0	1	4	4	9	82
3.56	1.38	130.38	67.62	69.34	1.4	2.84	0	1	4	4	9	82
3.58	1.39	131.925	68.01	69.73	1.4	2.81	0	1	4	4	8	83
3.6	1.4	133.478	68.37	70.1	1.39	2.83	0	1	4	4	8	83
3.62	1.42	135.042	68.69	70.42	1.39	2.81	0	1	4	3	7	84
3.64	1.43	136.614	69	70.74	1.38	2.83	0	1	4	3	7	84
3.66	1.44	138.196	69.32	71.06	1.38	2.82	0	1	5	3	7	85
3.68	1.46	139.787	69.63	71.38	1.38	2.82	0	1	5	3	7	85
3.7	1.47	141.388	69.94	71.69	1.38	2.8	0	1	5	2	6	86
3.72	1.48	142.998	70.26	72.01	1.37	2.77	0	1	5	2	5	87
3.74	1.5	144.617	70.57	72.33	1.37	2.77	0	1	5	2	5	87
3.76	1.51	146.246	70.89	72.65	1.37	2.77	0	1	5	2	5	87
3.78	1.52	147.884	71.2	72.97	1.36	2.75	0	1	5	2	5	87
3.8	1.54	149.532	71.51	73.29	1.36	2.77	0	1	5	2	5	86
3.82	1.55	151.188	71.83	73.61	1.36	2.74	0	1	5	1	4	88
3.84	1.56	152.855	72.14	73.93	1.36	2.77	0	1	5	2	5	87
3.86	1.58	154.531	72.46	74.25	1.35	2.76	0	1	6	2	4	87
3.88	1.59	156.216	72.77	74.56	1.35	2.74	0	1	6	1	4	88
3.9	1.6	157.91	73.08	74.88	1.35	2.77	0	1	6	2	4	87
3.92	1.62	159.614	73.4	75.2	1.35	2.75	0	1	6	1	3	88
3.94	1.63	161.328	73.71	75.52	1.34	2.77	0	1	6	2	4	87
3.96	1.64	163.051	74.03	75.84	1.34	2.77	0	1	6	2	4	88
3.98	1.65	164.783	74.34	76.16	1.34	2.75	0	1	6	1	3	88
4	1.67	166.525	74.65	76.48	1.34	2.75	0	1	6	1	3	89
4.02	1.68	168.276	74.97	76.8	1.34	2.77	0	1	6	2	4	88
4.04	1.69	170.037	75.28	77.11	1.33	2.75	0	1	6	1	3	89
4.06	1.71	171.807	75.6	77.43	1.33	2.77	0	1	6	2	4	88
4.08	1.72	173.586	75.91	77.75	1.33	2.74	0	1	6	1	3	89
4.1	1.73	175.375	76.22	78.07	1.33	2.76	0	1	6	2	3	88
4.12	1.75	177.173	76.54	78.39	1.33	2.76	0	1	6	2	3	88
4.14	1.76	178.981	76.85	78.71	1.32	2.73	0	1	7	1	3	89
4.16	1.77	180.798	77.17	79.03	1.32	2.76	0	1	7	2	3	88
4.18	1.78	182.625	77.48	79.35	1.32	2.73	0	1	7	1	3	89
4.2	1.8	184.461	77.79	79.67	1.32	2.76	0	1	7	2	3	88
4.22	1.81	186.307	78.11	79.98	1.32	2.76	0	1	7	2	3	88
4.24	1.82	188.162	78.42	80.3	1.32	2.74	0	1	7	1	3	89
4.26	1.83	190.027	78.74	80.62	1.32	2.74	0	1	7	1	3	89
4.28	1.85	191.901	79.05	80.94	1.31	2.77	0	1	7	2	3	88
4.3	1.86	193.784	79.36	81.26	1.31	2.74	0	1	7	1	3	89
4.32	1.87	195.677	79.68	81.58	1.31	2.77	0	1	7	2	3	88
4.34	1.89	197.58	79.99	81.9	1.31	2.74	0	1	7	1	3	89
4.36	1.9	199.492	80.31	82.22	1.31	2.74	0	1	7	1	3	89
4.38	1.91	201.413	80.62	82.54	1.31	2.77	0	1	7	2	3	88
4.4	1.92	203.344	80.93	82.85	1.31	2.74	0	1	7	1	3	89
4.42	1.94	205.284	81.25	83.17	1.31	2.76	0	1	7	2	3	88
4.44	1.95	207.234	81.56	83.49	1.3	2.74	0	1	7	1	2	88

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
4.46	1.96	209.194	81.85	83.79	1.3	2.76	0	1	7	2	3	88
4.48	1.97	211.163	82.14	84.09	1.3	2.75	0	1	7	2	3	88
4.5	1.99	213.141	82.44	84.39	1.3	2.75	0	1	7	2	3	88

SvS=Slow very Shallow; SS=Slow Shallow; SD=Slow Deep; FvS=Fast very Shallow; FS=Fast Shallow; FD=Fast Deep (for velocity and depth ranges refer to Birkhead 2010)

Table 3.13: Ecologically relevant hydraulic indicators at 10_Latonyanda

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.02	0.01	0	0.3	0.31	0.01	0.02	100	0	0	0	0	0
0.04	0.02	0	0.61	0.62	0.02	0.07	100	0	0	0	0	0
0.06	0.02	0.001	1.4	1.42	0.03	0.12	100	0	0	0	0	0
0.08	0.03	0.003	1.94	1.97	0.04	0.15	100	0	0	0	0	0
0.1	0.05	0.006	2.07	2.1	0.06	0.21	99	1	0	0	0	0
0.12	0.07	0.012	2.19	2.23	0.08	0.28	84	14	0	2	0	0
0.14	0.07	0.021	3.08	3.13	0.11	0.36	75	20	0	4	1	0
0.16	0.06	0.035	4.58	4.63	0.12	0.41	64	29	0	5	2	0
0.18	0.07	0.053	5.24	5.31	0.14	0.47	56	34	0	6	4	0
0.2	0.08	0.077	5.83	5.91	0.16	0.52	56	31	0	8	5	0
0.22	0.09	0.108	7.02	7.1	0.17	0.57	56	28	0	10	5	0
0.24	0.1	0.147	7.43	7.52	0.19	0.63	46	34	0	11	8	0
0.26	0.11	0.196	8.4	8.5	0.21	0.7	36	39	0	12	13	0
0.28	0.12	0.256	9.08	9.17	0.23	0.76	30	40	0	13	17	0
0.3	0.14	0.327	9.21	9.32	0.26	0.83	23	42	0	12	22	0
0.32	0.16	0.412	9.35	9.46	0.28	0.9	16	44	0	11	28	1
0.34	0.17	0.512	9.48	9.59	0.31	0.99	11	44	0	9	33	3
0.36	0.19	0.628	9.6	9.72	0.34	1.08	6	45	0	6	36	7
0.38	0.21	0.762	9.71	9.84	0.37	1.18	3	42	0	4	40	11
0.4	0.23	0.915	9.81	9.94	0.41	1.28	2	39	0	3	43	12
0.42	0.25	1.09	9.91	10.05	0.45	1.39	2	36	0	3	44	15
0.44	0.26	1.287	10	10.15	0.49	1.49	1	33	0	2	42	21
0.46	0.28	1.509	10.03	10.21	0.53	1.62	1	31	0	2	36	30
0.48	0.3	1.758	10.05	10.27	0.58	1.75	1	28	0	2	32	37
0.5	0.32	2.034	10.08	10.33	0.63	1.82	1	25	0	1	29	44
0.52	0.34	2.34	10.11	10.39	0.68	1.92	0	22	1	2	25	50
0.54	0.36	2.679	10.14	10.45	0.74	1.98	0	19	2	1	19	59
0.56	0.38	3.051	10.17	10.51	0.79	2.05	0	15	3	2	13	68
0.58	0.4	3.459	10.19	10.57	0.86	2.09	0	13	3	1	9	74
0.6	0.42	3.905	10.22	10.63	0.92	2.16	0	11	3	2	7	78
0.62	0.43	4.391	10.25	10.69	0.99	2.23	0	9	3	1	6	81
0.64	0.45	4.919	10.28	10.74	1.06	2.31	0	7	3	2	5	82
0.66	0.47	5.407	10.31	10.8	1.11	2.36	0	5	4	1	5	85
0.68	0.49	5.78	10.35	10.86	1.14	2.41	0	4	5	2	4	85
0.7	0.51	6.155	10.39	10.93	1.17	2.41	0	3	5	1	3	87
0.72	0.53	6.533	10.43	10.99	1.19	2.45	0	3	5	1	3	88
0.74	0.54	6.912	10.47	11.04	1.21	2.51	0	2	5	2	3	88
0.76	0.56	7.292	10.49	11.09	1.24	2.56	0	2	6	2	3	88
0.78	0.58	7.675	10.51	11.13	1.26	2.55	0	1	6	1	3	90
0.8	0.6	8.059	10.53	11.18	1.27	2.6	0	1	6	0	3	90
0.82	0.62	8.445	10.55	11.22	1.29	2.62	0	1	6	0	3	90
0.84	0.64	8.832	10.57	11.27	1.31	2.67	0	1	6	1	3	90
0.86	0.66	9.221	10.59	11.31	1.33	2.7	0	1	5	1	3	90
0.88	0.68	9.612	10.61	11.35	1.34	2.73	0	0	5	1	3	90

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.9	0.69	10.003	10.63	11.4	1.36	2.76	0	0	5	1	3	91
0.92	0.71	10.396	10.65	11.44	1.37	2.77	0	0	5	0	3	92
0.94	0.73	10.79	10.67	11.49	1.38	2.78	0	0	5	0	3	92
0.96	0.75	11.186	10.69	11.53	1.39	2.82	0	0	5	0	3	92
0.98	0.77	11.582	10.71	11.58	1.41	2.87	0	0	5	1	2	91
1	0.79	11.98	10.73	11.62	1.42	2.9	0	0	5	1	2	91
1.02	0.81	12.379	10.75	11.67	1.43	2.92	0	0	5	1	2	92
1.04	0.82	12.779	10.77	11.71	1.44	2.91	0	0	5	0	2	93
1.06	0.84	13.18	10.79	11.76	1.45	2.93	0	0	5	0	2	93
1.08	0.86	13.583	10.81	11.8	1.46	2.95	0	0	5	0	2	93
1.1	0.88	13.986	10.83	11.85	1.47	2.94	0	0	5	0	2	93
1.12	0.9	14.39	10.86	11.9	1.48	2.99	0	0	5	1	2	92
1.14	0.91	14.795	10.89	11.95	1.49	2.98	0	0	5	0	2	93
1.16	0.93	15.201	10.93	12	1.49	3.02	0	0	5	1	2	92
1.18	0.95	15.609	10.96	12.06	1.5	3.05	0	0	5	1	2	92
1.2	0.96	16.017	11.05	12.16	1.51	3.03	0	0	5	0	2	93
1.22	0.97	16.426	11.16	12.27	1.52	3.05	0	0	5	1	2	92
1.24	0.98	16.835	11.26	12.39	1.52	3.09	0	0	4	3	2	90
1.26	0.99	17.246	11.37	12.51	1.53	3.1	0	0	4	3	3	90
1.28	1	17.658	11.48	12.62	1.53	3.11	0	0	4	4	3	89
1.3	1.01	18.07	11.59	12.74	1.54	3.12	0	0	4	4	3	88
1.32	1.02	18.483	11.69	12.86	1.54	3.12	0	0	4	4	4	88
1.34	1.04	18.897	11.8	12.97	1.55	3.14	0	0	4	4	4	87
1.36	1.05	19.312	11.91	13.09	1.55	3.12	0	0	4	3	4	88
1.38	1.06	19.727	12.02	13.21	1.55	3.12	0	0	4	3	6	86
1.4	1.07	20.143	12.12	13.33	1.56	3.12	0	0	4	3	6	86
1.42	1.08	20.56	12.23	13.44	1.56	3.12	0	0	4	3	7	86
1.44	1.09	20.978	12.34	13.56	1.56	3.13	0	0	4	3	7	85
1.46	1.1	21.396	12.45	13.68	1.56	3.14	0	0	4	3	8	85
1.48	1.11	21.816	12.55	13.79	1.57	3.13	0	1	4	3	8	85
1.5	1.12	22.235	12.66	13.91	1.57	3.16	0	1	4	4	8	84
1.52	1.13	22.656	12.77	14.03	1.57	3.17	0	1	4	4	7	84
1.54	1.14	23.077	12.88	14.14	1.57	3.17	0	1	4	4	8	83
1.56	1.15	23.499	12.98	14.26	1.57	3.18	0	1	4	4	8	84
1.58	1.16	23.921	13.09	14.38	1.57	3.18	0	1	4	4	8	84
1.6	1.17	24.345	13.2	14.49	1.57	3.19	0	1	4	4	8	84
1.62	1.18	24.768	13.3	14.61	1.57	3.17	0	1	4	4	8	84
1.64	1.19	25.193	13.41	14.73	1.57	3.17	0	1	4	3	8	84
1.66	1.2	25.618	13.52	14.85	1.57	3.17	0	1	4	3	8	84
1.68	1.21	26.043	13.64	14.97	1.57	3.2	0	1	4	4	7	84
1.7	1.22	26.47	13.78	15.12	1.57	3.2	0	1	4	4	7	84
1.72	1.23	26.896	13.93	15.27	1.57	3.15	0	1	4	3	7	85
1.74	1.23	27.324	14.07	15.42	1.57	3.14	0	1	4	3	7	85
1.76	1.23	27.752	14.38	15.74	1.57	3.19	0	1	4	6	8	82
1.78	1.21	28.18	14.81	16.17	1.57	3.15	0	1	4	6	8	81
1.8	1.2	28.609	15.24	16.6	1.57	3.17	0	1	3	9	7	79
1.82	1.18	29.039	15.67	17.03	1.56	3.13	0	1	4	9	8	79
1.84	1.17	29.469	16.09	17.46	1.56	3.13	0	1	3	10	8	77
1.86	1.16	29.9	16.52	17.9	1.56	3.17	1	1	3	11	9	75
1.88	1.15	30.331	16.95	18.33	1.55	3.14	1	1	3	11	10	74
1.9	1.14	30.763	17.38	18.76	1.55	3.16	1	1	3	12	11	72
1.92	1.14	31.195	17.8	19.19	1.54	3.16	1	1	3	12	12	71
1.94	1.13	31.628	18.23	19.62	1.54	3.12	1	1	3	11	13	71
1.96	1.12	32.062	18.66	20.05	1.53	3.13	1	1	3	11	15	69
1.98	1.12	32.495	19.09	20.48	1.52	3.08	1	1	3	10	16	69
2	1.11	32.93	19.51	20.91	1.52	3.07	1	1	3	10	17	68

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
2.02	1.11	33.365	19.94	21.35	1.51	3.08	1	1	3	10	18	67
2.04	1.11	33.8	20.37	21.78	1.5	3.03	1	1	3	10	18	67
2.06	1.1	34.236	20.8	22.21	1.49	3.05	1	1	3	10	18	67
2.08	1.1	34.672	21.22	22.64	1.48	3	1	1	3	10	18	67
2.1	1.1	35.109	21.65	23.07	1.48	3.01	0	1	3	9	18	67
2.12	1.1	35.546	22.08	23.5	1.47	2.96	0	2	3	9	18	68
2.14	1.09	35.984	22.54	23.97	1.46	2.95	0	2	3	9	18	68
2.16	1.09	36.422	23.15	24.58	1.45	2.91	0	2	3	9	17	69
2.18	1.08	36.86	23.76	25.19	1.44	2.91	1	2	3	9	17	68
2.2	1.07	37.299	24.37	25.8	1.43	2.89	1	2	3	10	17	68

SvS=Slow very Shallow; SS=Slow Shallow; SD=Slow Deep; FvS=Fast very Shallow; FS=Fast Shallow; FD=Fast Deep (for velocity and depth ranges refer to Birkhead 2010)

Table 3.14: Ecologicall relevant hydraulic indicators at 11_Mutshindudi

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.02	0.01	0	0.48	0.49	0.02	0.08	100	0	0	0	0	0
0.04	0.01	0.001	2.01	2.03	0.03	0.11	100	0	0	0	0	0
0.06	0.03	0.004	2.77	2.8	0.05	0.17	100	0	0	0	0	0
0.08	0.04	0.009	3.42	3.46	0.07	0.23	100	0	0	0	0	0
0.1	0.05	0.017	4	4.07	0.08	0.28	98	0	0	2	0	0
0.12	0.07	0.03	4.26	4.35	0.1	0.35	84	12	0	4	1	0
0.14	0.07	0.043	5.22	5.33	0.11	0.37	58	36	0	4	2	0
0.16	0.09	0.064	5.59	5.73	0.13	0.44	46	46	0	4	4	0
0.18	0.1	0.091	5.97	6.14	0.15	0.5	37	51	0	5	7	0
0.2	0.12	0.123	6.35	6.54	0.17	0.57	32	53	0	6	9	0
0.22	0.13	0.166	6.52	6.74	0.19	0.65	26	53	0	7	14	0
0.24	0.15	0.218	6.61	6.86	0.22	0.73	16	58	0	6	20	0
0.26	0.17	0.28	6.7	6.98	0.25	0.81	11	56	0	5	28	0
0.28	0.19	0.352	6.79	7.1	0.28	0.91	7	54	0	5	35	0
0.3	0.2	0.438	6.87	7.22	0.31	1.01	4	50	0	4	41	0
0.32	0.22	0.539	6.96	7.34	0.35	1.12	3	47	0	3	44	4
0.34	0.23	0.639	7.48	7.88	0.38	1.2	5	41	0	6	34	15
0.36	0.24	0.786	7.51	7.94	0.43	1.34	4	35	0	7	31	22
0.38	0.26	0.952	7.76	8.2	0.48	1.47	4	31	0	8	29	28
0.4	0.26	1.092	8.4	8.86	0.51	1.54	6	27	0	12	23	32
0.42	0.26	1.245	9.04	9.53	0.54	1.61	6	25	0	14	20	34
0.44	0.27	1.409	9.37	9.88	0.56	1.7	7	23	0	16	16	38
0.46	0.28	1.587	9.71	10.23	0.59	1.74	6	22	0	16	14	42
0.48	0.29	1.779	10.04	10.59	0.61	1.8	6	21	0	16	13	44
0.5	0.3	1.984	10.37	10.94	0.64	1.87	5	20	0	14	15	45
0.52	0.31	2.203	10.75	11.35	0.67	1.91	4	19	2	12	17	46
0.54	0.31	2.437	11.24	11.86	0.69	1.96	4	16	3	12	19	46
0.56	0.32	2.686	11.72	12.37	0.71	1.98	4	13	5	13	20	45
0.58	0.33	2.95	12.2	12.89	0.74	2.02	4	12	6	14	21	45
0.6	0.34	3.23	12.68	13.4	0.76	2.05	4	10	6	14	21	44
0.62	0.34	3.526	13.21	13.95	0.78	2.09	4	9	6	16	21	45
0.64	0.35	3.838	13.74	14.51	0.8	2.09	3	8	6	15	22	45
0.66	0.35	4.167	14.27	15.06	0.82	2.1	3	8	7	14	24	45
0.68	0.36	4.514	14.8	15.62	0.84	2.13	3	7	7	15	24	45
0.7	0.37	4.878	15.33	16.17	0.86	2.12	3	7	6	14	24	47
0.72	0.38	5.259	15.87	16.73	0.88	2.12	2	7	6	13	24	48
0.74	0.38	5.659	16.36	17.25	0.9	2.16	2	6	6	14	22	49

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.76	0.39	6.077	16.83	17.74	0.92	2.15	2	6	6	14	23	49
0.78	0.4	6.514	17.31	18.25	0.94	2.17	2	6	5	12	23	51
0.8	0.41	6.97	17.85	18.82	0.95	2.2	2	6	5	13	24	51
0.82	0.42	7.446	18.3	19.29	0.97	2.19	1	6	5	10	25	52
0.84	0.43	7.942	18.76	19.77	0.99	2.19	1	6	5	10	24	54
0.86	0.44	8.457	19.21	20.24	1	2.23	1	6	5	11	23	55
0.88	0.45	8.994	19.66	20.72	1.02	2.24	1	5	5	10	24	55
0.9	0.46	9.551	20.11	21.19	1.04	2.29	1	5	5	10	23	56
0.92	0.47	10.129	20.56	21.67	1.05	2.29	1	5	5	9	23	57
0.94	0.48	10.728	21.02	22.14	1.07	2.32	1	4	5	10	21	59
0.96	0.48	11.349	21.73	22.88	1.09	2.36	1	4	4	11	21	59
0.98	0.48	11.993	22.67	23.84	1.1	2.35	1	4	4	12	20	59
1	0.49	12.658	23.17	24.36	1.11	2.34	1	4	4	11	19	61
1.02	0.5	13.347	23.51	24.71	1.13	2.37	1	4	4	11	19	61
1.04	0.52	14.058	23.86	25.07	1.14	2.37	1	4	4	8	19	64
1.06	0.53	14.792	24.13	25.35	1.16	2.4	1	4	4	9	19	63
1.08	0.54	15.551	24.37	25.61	1.17	2.39	1	4	4	6	20	66
1.1	0.56	16.332	24.62	25.87	1.19	2.44	1	3	4	6	19	67
1.12	0.57	17.139	24.86	26.13	1.2	2.48	0	3	4	6	18	68
1.14	0.59	17.942	25.11	26.39	1.22	2.5	0	3	4	4	19	69
1.16	0.6	18.602	25.36	26.65	1.22	2.52	0	3	4	5	17	70
1.18	0.62	19.273	25.55	26.85	1.22	2.49	0	3	4	4	16	73
1.2	0.63	19.956	25.69	27	1.23	2.52	0	3	4	4	16	73
1.22	0.65	20.651	25.83	27.14	1.23	2.51	0	2	4	4	15	74
1.24	0.67	21.358	25.97	27.28	1.23	2.49	0	2	5	2	13	78
1.26	0.68	22.077	26.27	27.59	1.24	2.52	0	2	4	3	12	77
1.28	0.69	22.808	26.63	27.96	1.24	2.51	0	2	5	3	11	79
1.3	0.7	23.55	26.99	28.32	1.25	2.51	0	2	5	4	9	80
1.32	0.71	24.305	27.35	28.68	1.25	2.51	0	2	5	5	8	81
1.34	0.72	25.071	27.72	29.05	1.25	2.52	0	2	5	5	7	81
1.36	0.73	25.849	28.08	29.41	1.26	2.54	0	2	5	5	7	81
1.38	0.74	26.639	28.44	29.78	1.26	2.55	0	2	5	5	7	81
1.4	0.75	27.441	28.8	30.14	1.27	2.54	0	2	5	5	7	81
1.42	0.76	28.255	29.16	30.5	1.27	2.57	0	2	5	5	8	80
1.44	0.77	29.081	29.52	30.87	1.27	2.61	0	2	5	6	9	79
1.46	0.78	29.918	29.88	31.23	1.28	2.6	0	1	5	6	8	80
1.48	0.8	30.768	30.24	31.59	1.28	2.58	0	1	5	5	9	80
1.5	0.81	31.629	30.6	31.96	1.28	2.6	0	1	5	5	9	79
1.52	0.82	32.502	30.88	32.24	1.29	2.61	0	1	5	5	9	80
1.54	0.83	33.387	31.04	32.41	1.29	2.6	0	1	5	4	10	80
1.56	0.85	34.284	31.2	32.57	1.29	2.6	0	1	5	4	10	80
1.58	0.87	35.192	31.36	32.74	1.3	2.64	0	1	5	4	10	80
1.6	0.88	36.113	31.52	32.9	1.3	2.61	0	1	5	3	10	81
1.62	0.9	37.045	31.68	33.07	1.3	2.64	0	1	5	3	11	80
1.64	0.91	37.99	31.84	33.23	1.31	2.66	0	1	5	3	10	82
1.66	0.93	38.946	32	33.4	1.31	2.65	0	1	5	2	9	83
1.68	0.94	39.914	32.1	33.51	1.32	2.69	0	1	5	2	8	84
1.7	0.96	40.894	32.19	33.62	1.32	2.67	0	1	5	2	8	85
1.72	0.98	41.886	32.29	33.72	1.33	2.71	0	1	5	2	7	85
1.74	1	42.889	32.39	33.83	1.33	2.71	0	1	5	2	7	85
1.76	1.01	43.905	32.48	33.94	1.33	2.72	0	1	5	2	6	87
1.78	1.03	44.932	32.58	34.05	1.34	2.71	0	1	5	1	5	88
1.8	1.05	45.971	32.67	34.16	1.34	2.76	0	1	5	2	5	87
1.82	1.06	47.022	32.77	34.27	1.35	2.77	0	1	5	2	5	88
1.84	1.08	48.085	32.87	34.38	1.35	2.78	0	1	5	2	4	88
1.86	1.1	49.16	32.96	34.49	1.36	2.79	0	1	5	2	4	88

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
1.88	1.11	50.246	33.06	34.59	1.36	2.77	0	1	5	1	4	90
1.9	1.13	51.345	33.15	34.7	1.37	2.79	0	1	5	1	3	90
1.92	1.15	52.455	33.25	34.81	1.37	2.8	0	1	5	1	3	90
1.94	1.16	53.577	33.35	34.92	1.38	2.84	0	1	5	1	3	90
1.96	1.18	54.711	33.44	35.03	1.39	2.81	0	1	5	1	3	91
1.98	1.2	55.857	33.54	35.14	1.39	2.82	0	1	5	1	3	91
2	1.21	57.015	33.65	35.26	1.4	2.83	0	0	5	1	3	91
2.02	1.23	58.184	33.76	35.38	1.4	2.87	0	0	5	1	3	90
2.04	1.25	59.366	33.87	35.51	1.41	2.85	0	0	5	1	3	91
2.06	1.26	60.559	33.98	35.63	1.41	2.89	0	0	5	1	3	90
2.08	1.28	61.764	34.09	35.75	1.42	2.88	0	0	5	1	2	91
2.1	1.29	62.981	34.2	35.88	1.42	2.91	0	0	5	1	3	91
2.12	1.31	64.21	34.31	36	1.43	2.91	0	0	5	1	3	91
2.14	1.32	65.45	34.42	36.12	1.44	2.89	0	0	5	1	2	92
2.16	1.34	66.703	34.54	36.24	1.44	2.92	0	0	5	2	2	91
2.18	1.36	67.967	34.65	36.37	1.45	2.93	0	0	5	2	2	91
2.2	1.37	69.243	34.76	36.49	1.45	2.94	0	0	5	2	2	91
2.22	1.39	70.531	34.87	36.61	1.46	2.96	0	0	5	2	2	91
2.24	1.4	71.831	34.98	36.74	1.46	2.95	0	0	5	1	3	91
2.26	1.42	73.143	35.09	36.86	1.47	3	0	0	5	2	3	90
2.28	1.43	74.466	35.2	36.98	1.48	2.98	0	0	5	1	2	91
2.3	1.45	75.802	35.31	37.11	1.48	3.02	0	0	5	2	3	90
2.32	1.46	77.149	35.42	37.23	1.49	3.03	0	0	5	2	3	90
2.34	1.48	78.508	35.53	37.35	1.49	3.05	0	0	5	2	3	90
2.36	1.5	79.879	35.63	37.46	1.5	3.07	0	0	5	2	3	90
2.38	1.51	81.262	35.73	37.58	1.5	3.09	0	0	5	2	3	91
2.4	1.53	82.656	35.83	37.69	1.51	3.09	0	0	5	2	3	91
2.42	1.54	84.063	35.94	37.8	1.52	3.07	0	0	5	1	2	92
2.44	1.56	85.481	36.04	37.92	1.52	3.08	0	0	5	1	2	92
2.46	1.57	86.911	36.14	38.03	1.53	3.09	0	0	5	1	2	92
2.48	1.59	88.353	36.24	38.15	1.53	3.09	0	0	4	1	2	92
2.5	1.61	89.807	36.34	38.26	1.54	3.09	0	0	4	1	2	92
2.52	1.62	91.273	36.45	38.38	1.55	3.13	0	0	4	2	3	91
2.54	1.64	92.75	36.55	38.49	1.55	3.12	0	0	4	1	2	92
2.56	1.65	94.239	36.65	38.6	1.56	3.16	0	0	4	2	3	91
2.58	1.67	95.741	36.75	38.72	1.56	3.17	0	0	4	2	3	91
2.6	1.68	97.254	36.85	38.83	1.57	3.16	0	0	4	1	2	92
2.62	1.7	98.779	36.95	38.95	1.57	3.17	0	0	4	1	2	92
2.64	1.71	100.315	37.06	39.06	1.58	3.18	0	0	4	1	2	92
2.66	1.73	101.864	37.16	39.18	1.59	3.2	0	0	4	1	2	92
2.68	1.74	103.424	37.26	39.29	1.59	3.25	0	0	4	2	3	91
2.7	1.76	104.996	37.36	39.4	1.6	3.26	0	0	4	2	3	91
2.72	1.77	106.58	37.46	39.52	1.6	3.27	0	0	4	2	3	91
2.74	1.79	108.176	37.57	39.63	1.61	3.29	0	0	4	2	3	91
2.76	1.8	109.784	37.67	39.75	1.62	3.3	0	0	4	1	2	92
2.78	1.82	111.403	37.77	39.86	1.62	3.29	0	0	4	1	2	92
2.8	1.83	113.035	37.87	39.98	1.63	3.3	0	0	4	1	2	93
2.82	1.85	114.678	37.97	40.09	1.63	3.3	0	0	4	1	2	93
2.84	1.86	116.333	38.07	40.2	1.64	3.31	0	0	4	1	2	93
2.86	1.88	118	38.18	40.32	1.64	3.35	0	0	4	1	2	92
2.88	1.89	119.679	38.28	40.43	1.65	3.34	0	0	4	1	2	92
2.9	1.91	121.369	38.38	40.55	1.66	3.36	0	0	4	1	2	92
2.92	1.92	123.072	38.48	40.66	1.66	3.38	0	0	4	1	2	92
2.94	1.94	124.786	38.62	40.81	1.67	3.38	0	0	4	1	2	92
2.96	1.95	126.512	38.77	40.96	1.67	3.37	0	0	4	1	2	93
2.98	1.96	128.25	38.92	41.11	1.68	3.38	0	0	4	1	2	92

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
3	1.98	129.999	39.06	41.26	1.68	3.42	0	0	4	1	3	91
3.02	1.99	131.761	39.21	41.41	1.69	3.43	0	0	4	1	3	92
3.04	2	133.534	39.35	41.56	1.7	3.42	0	0	4	1	2	92
3.06	2.01	135.319	39.5	41.71	1.7	3.43	0	0	4	1	2	92
3.08	2.03	137.116	39.64	41.87	1.71	3.45	0	0	4	1	2	92
3.1	2.04	138.925	39.79	42.02	1.71	3.49	0	0	4	2	3	91
3.12	2.05	140.746	39.93	42.17	1.72	3.47	0	0	4	1	2	92
3.14	2.06	142.578	40.08	42.32	1.72	3.52	0	0	4	2	3	91
3.16	2.08	144.423	40.22	42.47	1.73	3.53	0	0	4	2	3	91
3.18	2.09	146.279	40.37	42.62	1.74	3.5	0	0	4	1	3	92
3.2	2.1	148.147	40.51	42.77	1.74	3.52	0	0	4	1	3	92
3.22	2.11	150.027	40.66	42.92	1.75	3.56	0	0	4	2	3	91
3.24	2.13	151.918	40.8	43.07	1.75	3.56	0	0	4	2	3	91
3.26	2.14	153.822	40.95	43.22	1.76	3.53	0	0	4	1	3	92
3.28	2.15	155.737	41.09	43.37	1.76	3.52	0	0	4	1	3	92
3.3	2.16	157.664	41.24	43.53	1.77	3.57	0	0	4	2	3	91
3.32	2.18	159.603	41.38	43.68	1.77	3.59	0	0	4	2	3	91
3.34	2.19	161.554	41.53	43.83	1.78	3.57	0	0	4	1	3	92
3.36	2.2	163.517	41.67	43.98	1.78	3.59	0	0	4	1	3	92
3.38	2.21	165.491	41.82	44.13	1.79	3.64	0	0	4	2	3	91
3.4	2.22	167.477	41.97	44.28	1.79	3.65	0	0	4	2	3	91
3.42	2.24	169.475	42.11	44.43	1.8	3.62	0	0	4	1	3	92
3.44	2.25	171.485	42.26	44.58	1.8	3.64	0	0	4	1	3	92
3.46	2.26	173.507	42.4	44.73	1.81	3.69	0	0	4	2	3	91
3.48	2.27	175.541	42.55	44.88	1.81	3.7	0	0	4	2	3	91
3.5	2.29	177.586	42.69	45.03	1.82	3.67	0	0	4	1	3	92
3.52	2.3	179.643	42.84	45.18	1.82	3.69	0	0	4	1	3	92
3.54	2.31	181.712	42.98	45.34	1.83	3.74	0	0	4	2	3	91
3.56	2.32	183.793	43.13	45.49	1.83	3.71	0	0	4	1	3	92
3.58	2.33	185.886	43.27	45.64	1.84	3.71	0	0	4	1	3	92
3.6	2.35	187.99	43.42	45.79	1.84	3.76	0	0	4	2	3	91
3.62	2.36	190.107	43.56	45.94	1.85	3.75	0	0	4	2	3	91
3.64	2.37	192.235	43.71	46.09	1.85	3.73	0	0	4	1	3	92
3.66	2.38	194.375	43.85	46.24	1.86	3.74	0	0	4	1	3	92
3.68	2.4	196.526	44	46.39	1.86	3.79	0	0	4	2	3	92
3.7	2.41	198.69	44.14	46.54	1.87	3.8	0	0	4	2	3	92
3.72	2.42	200.865	44.29	46.69	1.87	3.74	0	0	4	1	3	92
3.74	2.43	203.053	44.43	46.84	1.88	3.75	0	0	4	1	2	92
3.76	2.44	205.252	44.56	46.98	1.88	3.81	0	0	4	2	3	92
3.78	2.46	207.463	44.67	47.1	1.89	3.82	0	0	4	2	3	92
3.8	2.47	209.685	44.78	47.22	1.89	3.84	0	0	4	2	3	92
3.82	2.49	211.92	44.9	47.34	1.9	3.86	0	0	4	1	3	92
3.84	2.5	214.166	45.01	47.46	1.9	3.83	0	0	4	1	2	93
3.86	2.51	216.424	45.12	47.58	1.91	3.84	0	0	4	1	2	93
3.88	2.53	218.694	45.23	47.71	1.91	3.86	0	0	4	1	2	93
3.9	2.54	220.976	45.34	47.83	1.92	3.87	0	0	4	1	2	93
3.92	2.56	223.27	45.46	47.95	1.92	3.88	0	0	4	1	2	93
3.94	2.57	225.575	45.57	48.07	1.93	3.89	0	0	4	1	2	94
3.96	2.58	227.892	45.68	48.19	1.93	3.93	0	0	3	1	2	93
3.98	2.6	230.222	45.79	48.31	1.94	3.94	0	0	3	1	2	93
4	2.61	232.562	45.9	48.43	1.94	3.94	0	0	3	1	2	93
4.02	2.62	234.915	46.01	48.55	1.95	3.96	0	0	3	1	2	93
4.04	2.64	237.28	46.13	48.67	1.95	3.97	0	0	3	1	2	93
4.06	2.65	239.656	46.24	48.8	1.96	3.98	0	0	3	1	2	93
4.08	2.66	242.044	46.35	48.92	1.96	3.95	0	0	3	1	2	94
4.1	2.68	244.444	46.46	49.04	1.96	3.97	0	0	3	1	2	94

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
4.12	2.69	246.856	46.57	49.16	1.97	3.98	0	0	3	1	2	94
4.14	2.7	249.279	46.69	49.28	1.97	3.99	0	0	3	1	2	94
4.16	2.72	251.715	46.8	49.4	1.98	3.99	0	0	3	1	2	94
4.18	2.73	254.162	46.91	49.52	1.98	4.04	0	0	3	1	1	93
4.2	2.75	256.621	47.02	49.64	1.99	4.04	0	0	3	1	2	93
4.22	2.76	259.092	47.13	49.77	1.99	4.05	0	0	3	1	2	93

SvS=Slow very Shallow; SS=Slow Shallow; SD=Slow Deep; FvS=Fast very Shallow; FS=Fast Shallow; FD=Fast Deep (for velocity and depth ranges refer to Birkhead 2010)

Table 3.15: Ecologically relevant hydraulic indicators at 12_Luvuvhu

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.02	0.01	0	0.67	0.68	0.02	0.06	100	0	0	0	0	0
0.04	0.02	0.001	1.38	1.38	0.03	0.09	100	0	0	0	0	0
0.06	0.03	0.002	2.14	2.14	0.03	0.12	100	0	0	0	0	0
0.08	0.04	0.005	2.47	2.48	0.05	0.16	100	0	0	0	0	0
0.1	0.05	0.008	3.57	3.58	0.05	0.17	99	1	0	0	0	0
0.12	0.05	0.013	5.57	5.59	0.05	0.18	88	12	0	0	0	0
0.14	0.05	0.022	7.46	7.49	0.06	0.2	81	19	0	0	0	0
0.16	0.06	0.036	9.06	9.09	0.06	0.23	76	24	0	0	0	0
0.18	0.06	0.051	12.75	12.79	0.07	0.23	81	19	0	0	0	0
0.2	0.07	0.08	14.27	14.32	0.08	0.27	74	25	0	1	0	0
0.22	0.09	0.121	15.11	15.17	0.09	0.32	59	37	0	2	1	0
0.24	0.11	0.173	15.55	15.62	0.11	0.37	49	45	0	3	3	0
0.26	0.12	0.236	15.93	16.02	0.12	0.42	37	54	0	3	5	0
0.28	0.14	0.311	16.28	16.38	0.14	0.47	22	67	0	3	8	0
0.3	0.16	0.399	16.56	16.68	0.15	0.52	11	76	0	2	11	0
0.32	0.18	0.503	16.82	16.96	0.17	0.59	8	76	0	2	14	1
0.34	0.19	0.622	17.04	17.2	0.19	0.64	6	74	0	1	17	2
0.36	0.21	0.762	17.16	17.35	0.21	0.72	5	70	0	2	20	3
0.38	0.23	0.923	17.27	17.49	0.23	0.78	3	68	0	1	24	5
0.4	0.25	1.107	17.38	17.63	0.26	0.87	3	62	0	2	25	8
0.42	0.27	1.316	17.53	17.81	0.28	0.94	2	58	0	2	25	13
0.44	0.28	1.554	17.73	18.03	0.31	1.02	2	54	0	1	24	19
0.46	0.3	1.827	17.92	18.25	0.34	1.12	2	49	0	2	20	26
0.48	0.32	2.142	18.11	18.46	0.37	1.21	2	45	0	2	15	36
0.5	0.33	2.507	18.31	18.68	0.41	1.32	2	40	0	3	10	45
0.52	0.35	2.939	18.43	18.83	0.45	1.44	1	36	2	2	9	50
0.54	0.37	3.5	18.48	18.89	0.51	1.6	1	30	3	2	8	56
0.56	0.39	3.816	18.53	18.96	0.53	1.64	1	28	3	2	7	58
0.58	0.41	4.149	18.62	19.07	0.55	1.66	1	25	5	2	6	61
0.6	0.42	4.497	18.75	19.21	0.57	1.69	0	23	7	0	7	63
0.62	0.44	4.862	18.88	19.35	0.58	1.74	1	19	8	2	6	64
0.64	0.46	5.244	19.02	19.49	0.6	1.76	0	16	11	1	6	66
0.66	0.47	5.642	19.15	19.62	0.62	1.8	1	12	13	2	5	67
0.68	0.49	6.058	19.28	19.76	0.64	1.83	1	8	16	2	6	67
0.7	0.51	6.491	19.41	19.9	0.66	1.84	1	6	17	2	5	69
0.72	0.52	6.941	19.55	20.04	0.68	1.89	1	5	17	2	5	70
0.74	0.45	7.408	23.87	24.37	0.69	1.92	4	4	15	15	5	58
0.76	0.44	7.894	25.46	25.97	0.71	1.97	5	3	14	19	4	55
0.78	0.44	8.397	26.81	27.33	0.72	2.02	6	3	13	22	4	52
0.8	0.45	8.919	27.45	27.97	0.73	1.99	5	3	13	20	6	52
0.82	0.46	9.458	28.08	28.6	0.74	2.03	5	3	12	20	8	51

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.84	0.47	10.017	28.71	29.24	0.75	2.05	4	4	12	17	12	51
0.86	0.47	10.593	29.48	30.02	0.76	2.05	3	5	11	12	18	50
0.88	0.48	11.189	30.36	30.9	0.77	2.06	2	6	11	10	20	50
0.9	0.48	11.804	31.27	31.82	0.78	2.07	2	6	11	10	22	49
0.92	0.46	12.438	34.37	34.92	0.79	2.09	4	6	10	15	22	44
0.94	0.41	13.091	40.89	41.45	0.79	2.13	6	5	8	24	19	38
0.96	0.41	13.764	42.67	43.24	0.79	2.13	6	5	8	24	20	36
0.98	0.41	14.456	44.45	45.02	0.79	2.15	6	5	8	25	21	36
1	0.42	15.168	46.23	46.8	0.79	2.1	5	7	8	19	25	37
1.02	0.42	15.9	48	48.59	0.79	2.1	4	7	8	18	25	38
1.04	0.43	16.652	48.86	49.45	0.79	2.14	4	8	7	18	24	39
1.06	0.45	17.424	49.54	50.13	0.79	2.1	3	8	7	15	24	42
1.08	0.46	18.216	50.22	50.82	0.79	2.1	2	10	7	9	29	42
1.1	0.47	19.03	50.9	51.5	0.79	2.07	2	10	7	7	30	44
1.12	0.49	19.863	51.58	52.19	0.79	2.08	2	10	7	7	30	45
1.14	0.5	20.718	52.26	52.88	0.79	2.07	1	10	7	5	31	46
1.16	0.51	21.593	52.88	53.5	0.79	2.05	1	10	7	6	28	48
1.18	0.53	22.49	53.12	53.75	0.8	2.06	1	11	6	5	28	50
1.2	0.55	23.408	53.36	54	0.8	2.05	1	11	7	3	27	53
1.22	0.57	24.347	53.6	54.25	0.8	2.07	1	10	7	3	26	54
1.24	0.58	25.307	53.84	54.5	0.8	2.06	0	9	8	2	24	57
1.26	0.6	26.29	54.08	54.75	0.81	2.07	0	9	8	2	19	62
1.28	0.62	27.294	54.32	55	0.81	2.03	0	9	8	1	14	68
1.3	0.64	28.319	54.56	55.25	0.82	2.03	0	8	9	1	12	70
1.32	0.65	29.367	54.81	55.5	0.82	2.06	0	8	9	2	9	72
1.34	0.67	30.437	55.05	55.75	0.82	2.07	0	7	9	2	9	73
1.36	0.69	31.53	55.29	56	0.83	2.09	0	7	9	2	8	74
1.38	0.71	32.644	55.53	56.25	0.83	2.09	0	7	9	2	7	75
1.4	0.72	33.781	55.72	56.45	0.84	2.05	0	5	11	1	6	77
1.42	0.74	34.941	55.83	56.57	0.84	2.05	0	5	11	1	5	78
1.44	0.76	36.124	55.95	56.69	0.85	2.07	0	4	11	1	4	79
1.46	0.78	37.329	56.06	56.82	0.86	2.08	0	4	12	1	4	80
1.48	0.8	38.558	56.17	56.94	0.86	2.1	0	3	12	1	3	80
1.5	0.81	39.809	56.29	57.07	0.87	2.11	0	3	12	1	3	81
1.52	0.83	41.084	56.4	57.19	0.87	2.13	0	2	13	1	3	81
1.54	0.85	42.382	56.51	57.31	0.88	2.14	0	2	13	1	3	81
1.56	0.87	43.704	56.63	57.44	0.89	2.12	0	2	13	1	3	81
1.58	0.89	45.049	56.74	57.56	0.89	2.12	0	2	13	1	3	82
1.6	0.91	46.418	56.86	57.68	0.9	2.12	0	1	13	1	2	83
1.62	0.92	47.811	56.97	57.81	0.91	2.11	0	1	13	0	2	84
1.64	0.94	49.228	57.08	57.93	0.92	2.12	0	1	13	0	2	84
1.66	0.96	50.668	57.2	58.06	0.92	2.13	0	1	13	0	2	84
1.68	0.98	52.133	57.31	58.18	0.93	2.16	0	1	13	0	2	84
1.7	1	53.622	57.42	58.3	0.94	2.18	0	1	13	0	2	85
1.72	1.01	55.136	57.54	58.43	0.94	2.18	0	1	12	0	2	85
1.74	1.03	56.674	57.65	58.55	0.95	2.2	0	1	12	0	1	86
1.76	1.05	58.236	57.76	58.67	0.96	2.21	0	1	12	1	1	85
1.78	1.07	59.824	57.88	58.8	0.97	2.22	0	1	12	1	1	85
1.8	1.09	61.436	58.01	58.94	0.98	2.22	0	1	12	0	1	86
1.82	1.1	63.073	58.14	59.07	0.98	2.25	0	1	12	1	1	85
1.84	1.12	64.735	58.27	59.21	0.99	2.25	0	1	12	1	1	86
1.86	1.14	66.422	58.39	59.34	1	2.27	0	1	11	1	1	86
1.88	1.16	68.134	58.52	59.48	1.01	2.26	0	1	11	0	1	87
1.9	1.17	69.88	58.65	59.61	1.02	2.3	0	0	11	1	1	86
1.92	1.19	71.341	58.78	59.75	1.02	2.3	0	0	11	1	1	86
1.94	1.21	72.798	58.91	59.88	1.02	2.32	0	0	11	1	1	86

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
1.96	1.23	74.252	59.04	60.02	1.03	2.35	0	0	11	1	2	86
1.98	1.24	75.702	59.16	60.16	1.03	2.33	0	0	11	1	1	86
2	1.26	77.148	59.29	60.29	1.03	2.31	0	0	11	1	1	86
2.02	1.28	78.591	59.52	60.53	1.04	2.35	0	1	11	1	2	85
2.04	1.29	80.031	59.94	60.97	1.04	2.32	0	0	11	1	1	86
2.06	1.3	81.467	60.36	61.41	1.04	2.36	0	0	11	2	2	85
2.08	1.31	82.9	60.78	61.84	1.04	2.34	0	0	11	1	2	85
2.1	1.32	84.33	61.2	62.28	1.04	2.37	0	1	11	2	3	84
2.12	1.33	85.757	61.62	62.72	1.05	2.37	0	0	11	2	2	84
2.14	1.34	87.18	62.04	63.16	1.05	2.35	0	1	11	2	3	84
2.16	1.35	88.601	62.46	63.59	1.05	2.35	0	1	11	2	2	84
2.18	1.36	90.018	62.88	64.03	1.05	2.37	0	1	10	3	2	83
2.2	1.37	91.433	63.3	64.47	1.05	2.39	0	1	10	2	5	82
2.22	1.38	92.845	63.72	64.91	1.05	2.37	0	1	10	2	3	83
2.24	1.4	94.254	64.14	65.34	1.05	2.39	0	1	10	4	4	82
2.26	1.41	95.661	64.56	65.78	1.05	2.37	0	1	10	2	5	82
2.28	1.42	97.065	64.98	66.22	1.05	2.38	0	1	10	3	4	82
2.3	1.43	98.466	65.4	66.66	1.05	2.39	0	1	10	2	6	80
2.32	1.44	99.865	65.82	67.09	1.05	2.37	0	1	10	2	5	82
2.34	1.45	101.261	66.24	67.53	1.05	2.38	0	1	10	3	5	80
2.36	1.46	102.654	66.66	67.97	1.05	2.36	0	1	10	2	5	81
2.38	1.47	104.045	67.08	68.41	1.05	2.36	0	1	10	3	5	81
2.4	1.48	105.434	67.5	68.84	1.05	2.38	0	1	10	3	6	80
2.42	1.49	106.821	67.92	69.28	1.05	2.38	0	1	10	3	5	81
2.44	1.5	108.205	68.34	69.72	1.05	2.39	0	1	10	3	5	80
2.46	1.51	109.587	68.75	70.16	1.05	2.37	0	1	10	2	5	81
2.48	1.53	110.966	69.17	70.59	1.05	2.37	0	1	10	3	5	81
2.5	1.54	112.344	69.48	70.92	1.05	2.38	0	1	10	3	5	81
2.52	1.56	113.719	69.54	70.99	1.05	2.38	0	1	10	2	5	81
2.54	1.58	115.092	69.59	71.05	1.05	2.41	0	1	10	2	5	82
2.56	1.6	116.463	69.64	71.12	1.05	2.38	0	1	10	1	4	83
2.58	1.61	117.832	69.69	71.19	1.05	2.41	0	1	10	2	4	82
2.6	1.63	119.199	69.74	71.25	1.05	2.39	0	1	10	1	3	84
2.62	1.65	120.564	69.79	71.32	1.05	2.41	0	1	10	1	4	83
2.64	1.67	121.926	69.84	71.39	1.05	2.42	0	1	11	1	3	84
2.66	1.69	123.287	69.9	71.45	1.04	2.4	0	1	11	0	3	85
2.68	1.71	124.646	69.95	71.52	1.04	2.4	0	1	11	0	3	85
2.7	1.73	126.003	70	71.58	1.04	2.43	0	1	11	0	3	85
2.72	1.75	127.359	70.05	71.65	1.04	2.44	0	1	11	0	3	85
2.74	1.76	128.712	70.1	71.72	1.04	2.42	0	1	11	0	2	86
2.76	1.78	130.063	70.15	71.78	1.04	2.42	0	1	11	0	1	87
2.78	1.8	131.413	70.2	71.85	1.04	2.46	0	1	11	0	1	86
2.8	1.82	132.761	70.26	71.92	1.04	2.43	0	1	11	0	1	87
2.82	1.84	134.107	70.31	71.98	1.04	2.43	0	1	12	0	1	86
2.84	1.86	135.451	70.36	72.05	1.04	2.41	0	1	12	0	1	87
2.86	1.88	136.794	70.41	72.12	1.04	2.43	0	1	12	0	1	86
2.88	1.89	138.135	70.46	72.18	1.03	2.43	0	0	12	0	0	87
2.9	1.91	139.474	70.51	72.25	1.03	2.41	0	0	12	0	0	88
2.92	1.93	140.812	70.57	72.32	1.03	2.43	0	0	12	0	0	87
2.94	1.95	142.148	70.81	72.56	1.03	2.44	0	0	12	0	1	86
2.96	1.96	143.482	71.04	72.8	1.03	2.44	0	0	12	0	1	86
2.98	1.97	144.815	71.27	73.04	1.03	2.45	0	1	12	0	1	86
3	1.99	146.146	71.51	73.28	1.03	2.44	0	0	12	1	1	85
3.02	2	147.476	71.74	73.52	1.03	2.44	0	0	12	1	1	85
3.04	2.01	148.804	71.97	73.76	1.03	2.44	0	0	12	1	1	85
3.06	2.03	150.13	72.21	74	1.03	2.45	0	0	12	1	2	84

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
3.08	2.04	151.455	72.44	74.24	1.02	2.46	0	0	12	1	2	84
3.1	2.05	152.779	72.67	74.48	1.02	2.46	0	0	12	1	2	84
3.12	2.07	154.101	72.91	74.72	1.02	2.46	0	0	12	1	2	84
3.14	2.08	155.421	73.14	74.96	1.02	2.46	0	0	12	1	2	84
3.16	2.09	156.741	73.39	75.22	1.02	2.44	0	0	12	1	2	85
3.18	2.11	158.058	73.65	75.48	1.02	2.46	0	0	12	1	2	84
3.2	2.12	159.375	73.9	75.74	1.02	2.47	0	1	12	1	2	84
3.22	2.13	160.69	74.16	76	1.02	2.45	0	1	12	1	2	84
3.24	2.14	162.003	74.41	76.25	1.02	2.47	0	1	12	1	2	83
3.26	2.16	163.315	74.67	76.51	1.01	2.45	0	1	13	1	2	84
3.28	2.17	164.626	74.92	76.77	1.01	2.48	0	1	12	1	2	83
3.3	2.18	165.935	75.18	77.03	1.01	2.46	0	1	12	1	2	84
3.32	2.19	167.244	75.43	77.29	1.01	2.48	0	1	12	1	3	83
3.34	2.21	168.55	75.71	77.57	1.01	2.46	0	1	13	1	2	84
3.36	2.22	169.856	75.99	77.86	1.01	2.49	0	1	12	2	3	82
3.38	2.23	171.16	76.27	78.14	1.01	2.49	0	1	12	2	3	82
3.4	2.24	172.463	76.54	78.42	1.01	2.47	0	1	12	1	3	83
3.42	2.25	173.765	76.82	78.7	1	2.49	0	1	12	2	3	82
3.44	2.27	175.065	77.1	78.99	1	2.5	0	1	12	1	3	82
3.46	2.28	176.364	77.38	79.27	1	2.47	0	1	13	1	2	83
3.48	2.29	177.662	77.66	79.55	1	2.47	0	1	13	1	2	83
3.5	2.3	178.959	77.93	79.83	1	2.47	0	1	13	1	2	83
3.52	2.31	180.254	78.21	80.11	1	2.47	0	1	13	1	2	83
3.54	2.32	181.548	78.49	80.4	1	2.47	0	1	13	1	2	83
3.56	2.34	182.842	78.77	80.68	0.99	2.48	0	1	13	1	3	82
3.58	2.35	184.133	79.05	80.96	0.99	2.48	0	1	13	1	3	82
3.6	2.36	185.424	79.32	81.24	0.99	2.45	0	1	13	1	2	83
3.62	2.37	186.714	79.5	81.43	0.99	2.46	0	1	13	1	2	83
3.64	2.39	188.002	79.57	81.51	0.99	2.48	0	1	13	1	3	82
3.66	2.41	189.29	79.65	81.6	0.99	2.46	0	1	13	1	2	83
3.68	2.43	190.576	79.72	81.69	0.98	2.49	0	1	13	1	2	83
3.7	2.45	191.861	79.8	81.78	0.98	2.49	0	1	13	1	2	83
3.72	2.46	193.145	79.87	81.86	0.98	2.47	0	1	13	1	2	83
3.74	2.48	194.428	79.95	81.95	0.98	2.49	0	1	13	1	2	83
3.76	2.5	195.709	80.02	82.04	0.98	2.47	0	1	14	0	1	84
3.78	2.52	196.99	80.1	82.12	0.98	2.49	0	1	13	1	2	83
3.8	2.53	198.27	80.17	82.21	0.98	2.47	0	1	14	0	1	84
3.82	2.55	199.548	80.24	82.3	0.97	2.49	0	1	14	0	1	84
3.84	2.57	200.826	80.32	82.39	0.97	2.47	0	1	14	0	1	85
3.86	2.59	202.102	80.39	82.47	0.97	2.5	0	1	14	0	1	84
3.88	2.6	203.377	80.47	82.56	0.97	2.5	0	1	14	0	1	84
3.9	2.62	204.652	80.54	82.65	0.97	2.48	0	1	14	0	0	85
3.92	2.64	205.925	80.62	82.74	0.97	2.5	0	1	14	0	1	84
3.94	2.66	207.197	80.7	82.83	0.97	2.48	0	1	14	0	0	85
3.96	2.67	208.469	80.78	82.93	0.97	2.48	0	0	14	0	0	85
3.98	2.69	209.739	80.86	83.02	0.96	2.48	0	0	15	0	0	85
4	2.71	211.008	80.95	83.11	0.96	2.47	0	0	15	0	0	85
4.02	2.73	212.277	81.03	83.21	0.96	2.48	0	0	15	0	1	84
4.04	2.74	213.544	81.11	83.3	0.96	2.5	0	0	15	1	1	83
4.06	2.76	214.81	81.19	83.4	0.96	2.5	0	0	14	1	1	83
4.08	2.78	216.076	81.27	83.49	0.96	2.48	0	0	15	0	1	84
4.1	2.79	217.34	81.36	83.58	0.96	2.51	0	0	15	1	1	83
4.12	2.81	218.604	81.44	83.68	0.95	2.51	0	0	15	1	1	83
4.14	2.83	219.867	81.52	83.77	0.95	2.51	0	0	15	1	1	83
4.16	2.84	221.128	81.65	83.92	0.95	2.49	0	0	15	0	1	84
4.18	2.84	222.389	82.25	84.52	0.95	2.51	0	0	15	1	1	83

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
4.2	2.84	223.649	82.85	85.12	0.95	2.51	0	0	15	1	2	82
4.22	2.84	224.908	83.45	85.72	0.95	2.49	0	0	15	1	2	82
4.24	2.84	226.166	84.05	86.32	0.95	2.48	0	1	15	1	2	82
4.26	2.86	227.423	84.21	86.5	0.95	2.5	0	1	15	1	2	81
4.28	2.87	228.679	84.38	86.67	0.94	2.5	0	1	15	1	2	81
4.3	2.89	229.934	84.55	86.84	0.94	2.51	0	1	15	1	3	80
4.32	2.9	231.188	84.72	87.02	0.94	2.51	0	1	15	1	3	80
4.34	2.91	232.442	84.89	87.19	0.94	2.52	0	1	15	1	3	80
4.36	2.93	233.695	85.05	87.36	0.94	2.5	0	1	15	1	2	81
4.38	2.94	234.946	85.22	87.53	0.94	2.52	0	1	15	1	3	80
4.4	2.96	236.197	85.39	87.71	0.94	2.52	0	1	15	1	3	80
4.42	2.97	237.447	85.56	87.88	0.93	2.49	0	1	15	1	2	81
4.44	2.98	238.697	85.73	88.05	0.93	2.52	0	1	15	1	3	80
4.46	3	239.945	85.89	88.23	0.93	2.51	0	1	15	1	3	80
4.48	3.01	241.193	86.06	88.4	0.93	2.49	0	1	15	1	2	80
4.5	3.03	242.439	86.23	88.57	0.93	2.49	0	1	15	1	2	81
4.52	3.04	243.685	86.4	88.75	0.93	2.52	0	1	15	1	2	80
4.54	3.05	244.93	86.57	88.92	0.93	2.49	0	1	16	1	1	82
4.56	3.07	246.175	86.73	89.09	0.92	2.49	0	1	16	1	1	82
4.58	3.08	247.418	86.9	89.26	0.92	2.49	0	1	16	1	1	82
4.6	3.1	248.661	87.07	89.44	0.92	2.49	0	1	16	1	1	82
4.62	3.11	249.902	87.24	89.61	0.92	2.49	0	1	16	1	1	82
4.64	3.13	251.144	87.41	89.78	0.92	2.51	0	1	16	1	2	81
4.66	3.14	252.384	87.58	89.96	0.92	2.49	0	1	16	1	1	82
4.68	3.15	253.623	87.74	90.13	0.92	2.49	0	1	16	1	1	82
4.7	3.17	254.862	87.91	90.3	0.92	2.51	0	1	16	1	2	81
4.72	3.18	256.1	88.08	90.48	0.91	2.49	0	1	16	1	1	82
4.74	3.19	257.337	88.25	90.65	0.91	2.48	0	1	16	1	1	82
4.76	3.21	258.573	88.42	90.82	0.91	2.51	0	1	16	1	2	81
4.78	3.22	259.809	88.58	90.99	0.91	2.51	0	1	16	1	2	81
4.8	3.24	261.044	88.75	91.17	0.91	2.48	0	1	16	1	1	81
4.82	3.25	262.278	88.92	91.34	0.91	2.5	0	1	16	1	2	81
4.84	3.26	263.511	89.09	91.51	0.91	2.5	0	1	16	1	2	81
4.86	3.28	264.744	89.26	91.69	0.9	2.47	0	1	16	1	1	81
4.88	3.29	265.976	89.42	91.86	0.9	2.5	0	1	16	1	2	81
4.9	3.31	267.207	89.59	92.03	0.9	2.49	0	1	16	1	2	81

SvS=Slow very Shallow; SS=Slow Shallow; SD=Slow Deep; FvS=Fast very Shallow; FS=Fast Shallow; FD=Fast Deep (for velocity and depth ranges refer to Birkhead 2010)

Table 3.16: Ecologically relevant hydraulic indicators at 13_Mutale1

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.02	0.01	0	0.02	0.04	0	0	100	0	0	0	0	0
0.04	0.02	0	0.04	0.09	0.01	0.03	100	0	0	0	0	0
0.06	0.03	0	0.06	0.13	0.02	0.08	100	0	0	0	0	0
0.08	0.03	0	0.11	0.22	0.04	0.15	100	0	0	0	0	0
0.1	0.01	0	1	1.14	0.03	0.11	100	0	0	0	0	0
0.12	0.02	0.001	2.8	2.97	0.02	0.06	99	1	0	0	0	0
0.14	0.04	0.002	3.22	3.41	0.02	0.06	99	1	0	0	0	0
0.16	0.05	0.003	3.59	3.8	0.02	0.06	98	2	0	0	0	0
0.18	0.07	0.005	3.95	4.19	0.02	0.08	97	3	0	0	0	0
0.2	0.07	0.009	5.06	5.32	0.03	0.09	76	24	0	0	0	0
0.22	0.07	0.014	6.67	6.95	0.03	0.11	58	42	0	0	0	0

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.24	0.09	0.02	6.95	7.29	0.03	0.12	54	46	0	0	0	0
0.26	0.1	0.029	7.26	7.69	0.04	0.14	50	50	0	0	0	0
0.28	0.12	0.041	7.6	8.11	0.05	0.17	48	52	0	0	0	0
0.3	0.13	0.056	8.07	8.67	0.05	0.2	39	61	0	0	0	0
0.32	0.14	0.075	8.87	9.56	0.06	0.22	23	76	0	0	0	0
0.34	0.15	0.098	9.54	10.33	0.07	0.25	27	72	0	0	1	0
0.36	0.16	0.128	10.12	11	0.08	0.28	28	70	0	1	1	0
0.38	0.17	0.163	10.7	11.68	0.09	0.32	28	68	0	1	3	0
0.4	0.18	0.206	11.29	12.36	0.1	0.36	25	69	0	2	4	1
0.42	0.19	0.257	11.88	13.05	0.11	0.41	25	67	0	2	4	2
0.44	0.2	0.317	12.47	13.73	0.13	0.44	21	69	0	2	5	3
0.46	0.21	0.388	13.06	14.41	0.14	0.5	21	67	0	3	6	3
0.48	0.22	0.471	13.76	15.22	0.16	0.56	21	64	0	4	7	4
0.5	0.23	0.567	14.61	16.2	0.17	0.58	17	67	0	3	7	6
0.52	0.23	0.677	15.91	17.63	0.19	0.63	20	61	0	5	7	8
0.54	0.23	0.804	17.22	19.05	0.2	0.68	21	56	0	6	7	10
0.56	0.24	0.948	18.1	20.06	0.22	0.75	19	53	1	7	9	11
0.58	0.25	1.112	18.59	20.65	0.24	0.81	18	49	2	8	10	13
0.6	0.26	1.297	19.08	21.25	0.26	0.87	14	45	6	8	13	15
0.62	0.28	1.506	19.72	22.01	0.28	0.92	12	41	9	7	13	18
0.64	0.29	1.739	20.4	22.79	0.3	0.99	10	39	9	7	16	19
0.66	0.28	2	22.07	24.57	0.32	1.04	10	36	9	8	16	21
0.68	0.27	2.29	24.66	27.23	0.34	1.12	13	30	8	12	15	22
0.7	0.27	2.613	26.68	29.32	0.36	1.17	13	25	9	14	15	22
0.72	0.28	2.969	28.32	31	0.38	1.2	13	23	10	15	15	24
0.74	0.28	3.363	29.81	32.55	0.4	1.28	14	20	10	18	15	24
0.76	0.29	3.796	30.96	33.74	0.42	1.37	13	17	10	19	16	25
0.78	0.3	4.271	32.1	34.92	0.44	1.41	10	19	10	15	19	27
0.8	0.31	4.791	33.07	35.94	0.47	1.46	7	21	9	12	22	29
0.82	0.32	5.36	33.96	36.87	0.49	1.5	5	21	9	10	23	32
0.84	0.33	5.98	34.86	37.81	0.51	1.61	5	19	9	10	24	32
0.86	0.34	6.654	35.75	38.74	0.54	1.7	5	18	9	10	24	33
0.88	0.36	7.386	36.69	39.73	0.57	1.74	4	17	9	10	25	35
0.9	0.37	8.18	37.79	40.87	0.59	1.79	4	17	8	9	26	37
0.92	0.37	9.039	38.88	42.01	0.62	1.85	4	15	8	10	26	38
0.94	0.39	9.966	39.49	42.65	0.65	1.9	3	14	8	9	26	39
0.96	0.4	10.966	40.03	43.24	0.68	1.96	2	13	8	8	25	44
0.98	0.42	12.043	40.57	43.82	0.71	1.98	2	13	8	6	24	47
1	0.43	13.2	41.09	44.39	0.74	2.02	2	12	8	6	23	50
1.02	0.45	14.442	41.61	44.95	0.78	2.1	1	10	7	6	21	54
1.04	0.46	15.773	42.12	45.5	0.81	2.14	1	9	8	6	19	57
1.06	0.48	17.199	42.64	46.06	0.85	2.2	1	8	7	6	17	60
1.08	0.49	18.722	43.21	46.67	0.89	2.2	1	8	7	5	17	62
1.1	0.5	20.002	44.27	47.76	0.91	2.19	1	8	6	4	16	65
1.12	0.51	21.288	45.33	48.83	0.93	2.22	1	7	6	6	14	65
1.14	0.51	22.606	46.37	49.89	0.95	2.24	1	6	7	8	14	65
1.16	0.52	23.955	47.42	50.96	0.97	2.26	1	6	6	8	13	66
1.18	0.53	25.335	48.5	52.05	0.99	2.26	1	5	7	8	13	66
1.2	0.54	26.747	49.59	53.15	1	2.35	1	4	6	10	13	65
1.22	0.55	28.188	50.68	54.26	1.02	2.3	1	4	6	8	13	67
1.24	0.54	29.66	53.13	56.72	1.03	2.31	1	4	7	11	11	66
1.26	0.53	31.161	56.29	59.9	1.04	2.37	2	3	6	14	13	62
1.28	0.51	32.693	60.48	64.11	1.05	2.33	2	3	6	17	11	60
1.3	0.5	34.253	64	67.64	1.06	2.43	3	3	6	21	10	57
1.32	0.5	35.842	67.28	70.93	1.07	2.34	2	3	6	19	14	56
1.34	0.5	37.46	69.31	72.97	1.07	2.41	3	3	6	21	14	55

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
1.36	0.5	39.107	72.91	76.59	1.08	2.44	2	3	5	19	19	52
1.38	0.5	40.781	75.18	78.87	1.08	2.45	2	4	5	17	20	52
1.4	0.51	42.484	77.66	81.36	1.08	2.49	2	4	5	16	22	51
1.42	0.51	44.214	80.45	84.15	1.08	2.41	2	4	5	14	24	51
1.44	0.52	45.972	82.35	86.06	1.08	2.4	2	4	5	14	24	51
1.46	0.53	47.757	84.15	87.87	1.08	2.4	1	4	5	12	26	51
1.48	0.53	49.57	85.95	89.68	1.08	2.39	1	4	5	11	26	52
1.5	0.54	51.409	87.76	91.49	1.08	2.43	1	4	5	11	27	51
1.52	0.55	53.275	89.56	93.29	1.08	2.42	1	4	5	10	29	50
1.54	0.56	55.167	91.36	95.1	1.08	2.41	1	5	5	9	29	52
1.56	0.57	57.086	93.16	96.91	1.08	2.38	1	5	5	8	27	55
1.58	0.58	59.031	94.97	98.72	1.07	2.39	1	5	5	8	25	56
1.6	0.59	61.001	95.68	99.44	1.07	2.39	1	5	5	8	22	60
1.62	0.61	62.998	96.02	99.78	1.07	2.38	1	5	5	5	21	63
1.64	0.63	65.02	96.36	100.12	1.07	2.34	0	5	5	4	21	65
1.66	0.65	67.068	96.69	100.46	1.07	2.32	0	5	5	3	19	67
1.68	0.67	69.141	97.03	100.8	1.07	2.33	0	5	5	2	19	68
1.7	0.68	71.24	97.36	101.13	1.07	2.33	0	5	5	2	17	71
1.72	0.7	73.363	97.7	101.47	1.07	2.32	0	5	6	2	16	72
1.74	0.72	75.511	98.03	101.81	1.07	2.33	0	4	6	2	13	75
1.76	0.74	77.684	98.31	102.1	1.07	2.34	0	4	6	2	12	76
1.78	0.75	79.881	98.59	102.38	1.07	2.32	0	4	7	1	10	78
1.8	0.77	82.103	98.87	102.67	1.08	2.32	0	3	7	1	9	80
1.82	0.79	84.35	99.07	102.87	1.08	2.31	0	3	7	1	7	81
1.84	0.81	86.62	99.25	103.06	1.08	2.33	0	3	7	1	6	82
1.86	0.83	88.914	99.43	103.25	1.08	2.31	0	2	8	1	5	84
1.88	0.85	91.233	99.62	103.44	1.08	2.34	0	2	8	1	4	85
1.9	0.86	93.575	99.8	103.63	1.08	2.34	0	2	8	1	4	85
1.92	0.88	95.941	99.98	103.82	1.09	2.35	0	2	8	1	3	86
1.94	0.9	98.331	100.16	104.01	1.09	2.35	0	2	9	0	3	86
1.96	0.92	100.743	100.35	104.2	1.09	2.38	0	2	9	1	3	86
1.98	0.94	103.18	100.53	104.39	1.09	2.4	0	1	9	1	2	86
2	0.96	105.639	100.71	104.58	1.1	2.39	0	1	9	1	2	87
2.02	0.97	108.122	100.89	104.77	1.1	2.4	0	1	9	1	2	87
2.04	0.99	110.628	101.07	104.96	1.1	2.38	0	1	9	1	1	88
2.06	1.01	113.156	101.26	105.15	1.11	2.39	0	1	9	1	1	88
2.08	1.03	115.707	101.44	105.34	1.11	2.38	0	1	9	1	1	88
2.1	1.05	118.282	101.62	105.53	1.11	2.39	0	1	9	1	1	88
2.12	1.07	120.878	101.8	105.72	1.11	2.42	0	1	9	1	2	87
2.14	1.08	123.497	101.99	105.91	1.12	2.42	0	0	9	1	2	87
2.16	1.1	126.139	102.17	106.1	1.12	2.43	0	0	9	1	2	87
2.18	1.12	128.803	102.35	106.29	1.12	2.44	0	0	9	1	2	88
2.2	1.14	131.489	102.53	106.48	1.13	2.46	0	0	9	1	2	88
2.22	1.16	134.197	102.71	106.66	1.13	2.44	0	0	9	1	1	88
2.24	1.17	136.928	102.9	106.85	1.13	2.45	0	0	9	1	1	89
2.26	1.19	139.68	103.08	107.04	1.14	2.46	0	0	9	1	1	89
2.28	1.21	142.454	103.26	107.23	1.14	2.46	0	0	9	1	1	89
2.3	1.23	145.25	103.44	107.42	1.14	2.49	0	0	9	1	1	88
2.32	1.24	148.067	103.63	107.61	1.15	2.5	0	0	9	1	1	88
2.34	1.26	150.907	103.81	107.8	1.15	2.5	0	0	9	1	1	88
2.36	1.28	153.767	103.99	107.99	1.15	2.49	0	0	9	1	1	88
2.38	1.3	156.65	104.17	108.18	1.16	2.46	0	0	9	1	1	89
2.4	1.32	159.553	104.35	108.37	1.16	2.46	0	0	9	1	1	89
2.42	1.33	162.478	104.54	108.56	1.17	2.51	0	0	9	1	1	89
2.44	1.35	165.424	104.72	108.75	1.17	2.52	0	0	9	1	1	89
2.46	1.37	168.391	104.9	108.94	1.17	2.56	0	0	9	1	1	88

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
2.48	1.39	171.379	105.08	109.13	1.18	2.57	0	0	9	1	1	88
2.5	1.4	174.389	105.27	109.32	1.18	2.59	0	0	9	1	1	88
2.52	1.42	177.419	105.45	109.51	1.18	2.59	0	0	9	1	1	88
2.54	1.44	180.47	105.63	109.7	1.19	2.59	0	0	9	1	1	88
2.56	1.46	183.542	105.81	109.89	1.19	2.57	0	0	9	1	1	89
2.58	1.47	186.634	106	110.08	1.19	2.56	0	0	9	1	1	89
2.6	1.49	189.747	106.18	110.27	1.2	2.58	0	0	9	1	1	89
2.62	1.51	192.881	106.36	110.46	1.2	2.59	0	0	9	1	1	89
2.64	1.53	196.035	106.54	110.65	1.21	2.62	0	0	9	1	1	89
2.66	1.54	199.21	106.72	110.83	1.21	2.63	0	0	9	1	1	89
2.68	1.56	202.405	106.91	111.02	1.21	2.62	0	0	9	1	1	89
2.7	1.58	205.62	107.09	111.21	1.22	2.62	0	0	9	1	1	89
2.72	1.6	208.856	107.25	111.39	1.22	2.64	0	0	9	1	1	89
2.74	1.61	212.111	107.42	111.56	1.22	2.62	0	0	9	0	1	90
2.76	1.63	215.387	107.59	111.73	1.23	2.64	0	0	8	1	1	89
2.78	1.65	218.683	107.75	111.91	1.23	2.61	0	0	9	0	1	90
2.8	1.67	221.999	107.92	112.08	1.23	2.64	0	0	8	1	1	89
2.82	1.68	225.335	108.09	112.26	1.24	2.63	0	0	9	0	1	90
2.84	1.7	228.69	108.25	112.43	1.24	2.66	0	0	8	1	1	89
2.86	1.72	232.066	108.42	112.6	1.25	2.66	0	0	8	1	1	89
2.88	1.74	235.461	108.59	112.78	1.25	2.69	0	0	8	0	1	90
2.9	1.75	238.876	108.75	112.95	1.25	2.72	0	0	8	1	1	89
2.92	1.77	242.31	108.92	113.13	1.26	2.71	0	0	8	0	1	90
2.94	1.79	245.764	109.06	113.28	1.26	2.71	0	0	8	0	1	90
2.96	1.81	249.238	109.16	113.39	1.26	2.72	0	0	8	0	1	90
2.98	1.82	252.731	109.25	113.5	1.27	2.75	0	0	8	1	1	89
3	1.84	256.244	109.34	113.61	1.27	2.74	0	0	8	0	1	90
3.02	1.86	259.776	109.43	113.71	1.28	2.75	0	0	8	0	1	90
3.04	1.88	263.327	109.52	113.82	1.28	2.78	0	0	8	1	1	89
3.06	1.9	266.897	109.61	113.93	1.28	2.75	0	0	8	0	1	91
3.08	1.92	270.487	109.7	114.04	1.29	2.79	0	0	8	0	1	90
3.1	1.94	274.096	109.79	114.14	1.29	2.76	0	0	8	0	1	91
3.12	1.95	277.724	109.88	114.25	1.29	2.8	0	0	8	0	1	90
3.14	1.97	281.371	109.97	114.36	1.3	2.78	0	0	8	0	1	91
3.16	1.99	285.037	110.06	114.47	1.3	2.78	0	0	8	0	1	91
3.18	2.01	288.722	110.15	114.57	1.3	2.81	0	0	8	0	1	90
3.2	2.03	292.426	110.24	114.68	1.31	2.8	0	0	8	0	1	91
3.22	2.05	296.149	110.33	114.79	1.31	2.83	0	0	8	0	1	91
3.24	2.06	299.89	110.42	114.9	1.32	2.8	0	0	8	0	0	91
3.26	2.08	303.651	110.51	115	1.32	2.84	0	0	8	0	1	91
3.28	2.1	307.43	110.6	115.11	1.32	2.83	0	0	8	0	0	92
3.3	2.12	311.228	110.69	115.22	1.33	2.85	0	0	8	0	1	91
3.32	2.14	315.044	110.78	115.33	1.33	2.86	0	0	8	0	1	91
3.34	2.16	318.879	110.87	115.43	1.33	2.88	0	0	8	0	0	92
3.36	2.17	322.732	110.96	115.54	1.34	2.91	0	0	8	0	1	91
3.38	2.19	326.604	111.05	115.65	1.34	2.89	0	0	8	0	0	92
3.4	2.21	330.495	111.14	115.75	1.35	2.93	0	0	8	0	1	91
3.42	2.23	334.404	111.23	115.86	1.35	2.91	0	0	8	0	0	92
3.44	2.25	338.331	111.32	115.97	1.35	2.94	0	0	8	0	1	91
3.46	2.26	342.276	111.4	116.08	1.36	2.95	0	0	8	0	1	91
3.48	2.28	346.24	111.49	116.18	1.36	2.93	0	0	8	0	0	92
3.5	2.3	350.222	111.58	116.28	1.36	2.92	0	0	8	0	0	92
3.52	2.32	354.222	111.65	116.38	1.37	2.96	0	0	8	0	1	91
3.54	2.34	358.241	111.73	116.47	1.37	2.96	0	0	8	0	1	91
3.56	2.36	362.277	111.8	116.56	1.38	2.96	0	0	8	0	1	91
3.58	2.37	366.332	111.88	116.66	1.38	2.94	0	0	8	0	0	92

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
3.6	2.39	370.404	111.95	116.75	1.38	2.95	0	0	8	0	0	92
3.62	2.41	374.495	112.02	116.84	1.39	2.96	0	0	8	0	0	92
3.64	2.43	378.604	112.1	116.93	1.39	2.99	0	0	8	0	1	91
3.66	2.45	382.73	112.17	117.03	1.39	3	0	0	8	0	1	91
3.68	2.47	386.874	112.25	117.12	1.4	3	0	0	8	0	1	91
3.7	2.49	391.036	112.32	117.21	1.4	2.98	0	0	8	0	0	92
3.72	2.5	395.216	112.4	117.31	1.4	2.99	0	0	8	0	0	92
3.74	2.52	399.414	112.47	117.4	1.41	2.99	0	0	8	0	0	92
3.76	2.54	403.629	112.55	117.49	1.41	3.03	0	0	7	0	1	91
3.78	2.56	407.863	112.62	117.59	1.42	3.04	0	0	7	0	1	91
3.8	2.58	412.113	112.7	117.68	1.42	3.04	0	0	7	0	1	91

SvS=Slow very Shallow; SS=Slow Shallow; SD=Slow Deep; FvS=Fast very Shallow; FS=Fast Shallow; FD=Fast Deep (for velocity and depth ranges refer to Birkhead 2010)

Table 3.17: Ecologically relevant hydraulic indicators at 14_Mutale2

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.02	0.01	0	0.19	0.19	0.01	0.05	100	0	0	0	0	0
0.04	0.02	0	0.37	0.38	0.03	0.12	100	0	0	0	0	0
0.06	0.03	0.001	0.62	0.64	0.06	0.2	100	0	0	0	0	0
0.08	0.03	0.003	1.07	1.11	0.08	0.26	99	0	0	1	0	0
0.1	0.04	0.005	1.53	1.58	0.09	0.31	96	1	0	3	0	0
0.12	0.05	0.01	1.97	2.04	0.11	0.36	86	9	0	5	0	0
0.14	0.06	0.017	2.41	2.5	0.12	0.41	78	15	0	6	1	0
0.16	0.07	0.026	2.85	2.96	0.14	0.46	70	20	0	7	2	0
0.18	0.08	0.039	3.29	3.43	0.16	0.52	59	28	0	8	4	0
0.2	0.08	0.056	3.97	4.13	0.17	0.56	52	34	0	9	6	0
0.22	0.08	0.078	5.52	5.7	0.19	0.6	54	29	0	12	6	0
0.24	0.09	0.104	5.92	6.12	0.2	0.64	47	33	0	12	8	0
0.26	0.1	0.136	6.31	6.54	0.21	0.68	42	35	0	13	11	0
0.28	0.11	0.175	7.03	7.28	0.22	0.71	39	35	0	14	13	0
0.3	0.12	0.221	7.61	7.9	0.24	0.74	32	37	0	14	16	0
0.32	0.13	0.275	8.08	8.42	0.25	0.78	25	40	0	13	20	1
0.34	0.14	0.337	9.29	9.66	0.27	0.8	22	42	0	13	23	1
0.36	0.15	0.409	9.74	10.16	0.28	0.86	22	37	0	15	23	3
0.38	0.16	0.49	10.18	10.64	0.3	0.88	19	37	0	15	25	5
0.4	0.18	0.583	10.55	11.06	0.31	0.92	14	38	0	13	29	6
0.42	0.19	0.687	10.93	11.47	0.33	0.93	11	38	0	12	30	9
0.44	0.21	0.804	11.11	11.68	0.35	0.96	8	38	0	10	32	12
0.46	0.22	0.934	11.2	11.81	0.37	1.01	6	36	0	8	35	15
0.48	0.24	1.079	11.3	11.93	0.39	1.02	3	36	0	5	36	19
0.5	0.26	1.238	11.4	12.07	0.42	1.07	2	33	0	4	37	23
0.52	0.27	1.413	11.99	12.7	0.44	1.09	3	30	1	5	34	28
0.54	0.27	1.605	12.8	13.55	0.46	1.12	4	26	1	8	30	31
0.56	0.27	1.815	13.69	14.5	0.49	1.13	5	22	2	13	25	33
0.58	0.28	2.043	14.15	15	0.51	1.17	5	19	2	14	23	36
0.6	0.29	2.29	14.59	15.48	0.53	1.22	5	17	2	16	22	38
0.62	0.3	2.558	15.05	15.99	0.56	1.26	5	16	3	15	20	42
0.64	0.31	2.847	15.59	16.58	0.58	1.27	4	15	3	13	19	47
0.66	0.32	3.159	16.17	17.2	0.61	1.32	3	13	4	13	18	48
0.68	0.33	3.494	16.74	17.8	0.63	1.36	3	12	4	14	19	48
0.7	0.34	3.853	17.12	18.24	0.66	1.38	3	10	5	13	19	51
0.72	0.35	4.237	17.61	18.78	0.68	1.4	2	10	5	10	21	52

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
0.74	0.36	4.647	18.08	19.29	0.71	1.47	2	8	5	13	20	51
0.76	0.37	5.085	18.55	19.79	0.73	1.52	2	8	5	11	22	52
0.78	0.38	5.551	19.02	20.29	0.76	1.57	2	7	5	11	23	52
0.8	0.4	6.046	19.48	20.8	0.78	1.61	1	6	5	10	25	52
0.82	0.4	6.571	20.09	21.44	0.81	1.65	1	6	5	10	24	54
0.84	0.41	7.127	20.76	22.14	0.84	1.68	1	5	5	11	22	57
0.86	0.42	7.716	21.43	22.84	0.86	1.75	1	4	5	12	22	56
0.88	0.43	8.339	21.85	23.29	0.89	1.8	1	4	5	12	20	58
0.9	0.45	8.996	22.01	23.49	0.92	1.86	1	4	5	10	19	61
0.92	0.46	9.688	22.17	23.68	0.95	1.91	1	4	5	7	21	62
0.94	0.48	10.417	22.34	23.87	0.97	1.99	1	4	4	6	21	64
0.96	0.49	11.184	22.74	24.3	1	2.05	1	4	4	6	21	65
0.98	0.5	11.99	23.38	24.97	1.03	2.1	1	4	4	6	20	65
1	0.5	12.836	24.32	25.93	1.06	2.17	1	3	4	9	19	64
1.02	0.5	13.723	25.23	26.86	1.09	2.21	1	3	4	11	17	65
1.04	0.51	14.652	25.76	27.39	1.12	2.29	1	3	4	11	17	64
1.06	0.52	15.625	26.29	27.93	1.15	2.32	1	3	4	10	16	66
1.08	0.53	16.642	26.91	28.55	1.18	2.4	1	2	4	12	15	66
1.1	0.52	17.705	28.36	30.02	1.21	2.44	1	2	3	12	16	65
1.12	0.52	18.815	29.38	31.04	1.23	2.49	1	2	3	14	16	64
1.14	0.54	19.973	29.56	31.23	1.26	2.54	1	2	3	12	17	65
1.16	0.55	21.18	29.88	31.55	1.29	2.59	1	2	3	10	16	67
1.18	0.56	22.438	30.21	31.88	1.32	2.65	0	2	3	7	19	67
1.2	0.58	23.747	30.54	32.21	1.34	2.75	0	2	3	6	20	68
1.22	0.59	25.109	30.87	32.55	1.37	2.78	0	2	3	5	21	68
1.24	0.61	26.525	31.2	32.88	1.4	2.8	0	2	3	5	20	70
1.26	0.62	27.871	31.53	33.21	1.43	2.86	0	2	3	4	20	70
1.28	0.63	29.027	31.83	33.52	1.44	2.92	0	2	3	5	19	71
1.3	0.65	30.203	32.03	33.72	1.45	2.96	0	2	3	4	19	71
1.32	0.66	31.396	32.23	33.93	1.46	2.99	0	2	3	3	18	74
1.34	0.68	32.608	32.43	34.13	1.48	2.98	0	2	3	2	17	76
1.36	0.7	33.839	32.63	34.34	1.49	2.97	0	2	3	2	15	77
1.38	0.71	35.087	32.83	34.54	1.5	3.01	0	2	3	2	12	81
1.4	0.73	36.354	33.15	34.86	1.51	3.05	0	2	3	2	11	82
1.42	0.73	37.638	33.68	35.41	1.52	3.09	0	1	3	4	9	82
1.44	0.74	38.941	34.29	36.03	1.53	3.1	0	1	3	4	9	82
1.46	0.75	40.261	34.9	36.66	1.54	3.16	0	1	3	7	7	81
1.48	0.75	41.598	35.51	37.28	1.55	3.13	0	1	3	6	8	82
1.5	0.76	42.953	36.12	37.9	1.56	3.14	0	1	3	7	7	82
1.52	0.77	44.325	36.73	38.52	1.57	3.17	0	1	3	8	7	81
1.54	0.78	45.715	37.33	39.14	1.58	3.19	0	1	3	7	8	80
1.56	0.78	47.121	37.94	39.76	1.59	3.24	0	1	3	7	9	79
1.58	0.79	48.545	38.55	40.38	1.59	3.21	0	1	3	7	9	80
1.6	0.79	49.985	39.49	41.35	1.6	3.24	0	1	3	8	10	78
1.62	0.78	51.442	40.93	42.81	1.6	3.2	0	1	3	8	11	77
1.64	0.77	52.916	42.76	44.67	1.61	3.21	1	1	3	11	10	74
1.66	0.76	54.407	44.6	46.53	1.61	3.29	1	1	3	14	12	70
1.68	0.75	55.914	46.44	48.39	1.61	3.3	1	1	3	16	12	68
1.7	0.74	57.437	48.27	50.26	1.61	3.27	1	1	3	18	11	67
1.72	0.73	58.977	50.09	52.1	1.61	3.21	1	1	3	17	13	66
1.74	0.73	60.533	51.26	53.3	1.61	3.26	1	1	3	17	14	64
1.76	0.74	62.106	52.21	54.27	1.61	3.29	1	1	3	15	17	64
1.78	0.75	63.694	52.87	54.95	1.6	3.21	1	1	3	12	19	65
1.8	0.77	65.298	53.29	55.38	1.6	3.25	0	1	3	9	21	65
1.82	0.78	66.918	53.85	55.97	1.6	3.18	0	1	3	8	21	66
1.84	0.79	68.555	54.48	56.62	1.6	3.17	0	2	3	5	25	66

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
1.86	0.8	70.206	55.11	57.27	1.59	3.22	0	2	3	6	23	66
1.88	0.81	71.874	55.74	57.92	1.59	3.17	0	2	3	5	22	69
1.9	0.82	73.557	56.37	58.58	1.59	3.17	0	2	3	4	22	69
1.92	0.83	75.256	57	59.23	1.59	3.25	0	2	3	6	20	69
1.94	0.84	76.97	57.61	59.87	1.59	3.19	0	2	3	6	18	71
1.96	0.86	78.7	57.93	60.21	1.58	3.22	0	2	3	5	16	75
1.98	0.87	80.445	58.25	60.54	1.58	3.22	0	2	3	5	15	76
2	0.89	82.205	58.57	60.88	1.58	3.19	0	2	3	4	13	78
2.02	0.91	83.98	58.77	61.11	1.58	3.21	0	2	3	4	11	81
2.04	0.92	85.771	59.06	61.42	1.58	3.2	0	2	3	3	10	82
2.06	0.93	87.577	59.44	61.83	1.58	3.17	0	1	3	3	9	83
2.08	0.95	89.397	59.83	62.24	1.57	3.15	0	1	3	2	9	85
2.1	0.96	91.233	60.21	62.65	1.57	3.21	0	1	3	3	9	84
2.12	0.98	93.083	60.59	63.06	1.57	3.18	0	1	3	3	8	85
2.14	0.99	94.949	60.95	63.44	1.57	3.13	0	1	3	3	7	86
2.16	1.01	96.829	61.28	63.8	1.57	3.14	0	1	3	2	6	87
2.18	1.02	98.724	61.61	64.16	1.57	3.14	0	1	4	3	6	86
2.2	1.03	100.633	61.94	64.52	1.57	3.14	0	1	4	2	7	87
2.22	1.05	102.557	62.27	64.88	1.57	3.14	0	1	4	2	5	89
2.24	1.06	104.496	62.6	65.24	1.57	3.19	0	1	4	3	5	88
2.26	1.08	106.449	62.95	65.61	1.57	3.16	0	1	4	3	4	89
2.28	1.09	108.417	63.3	65.99	1.57	3.13	0	1	4	2	5	89
2.3	1.11	110.399	63.65	66.37	1.57	3.15	0	1	4	2	4	89
2.32	1.12	112.395	64	66.75	1.57	3.19	0	1	4	3	6	86
2.34	1.13	114.406	64.35	67.13	1.57	3.14	0	1	4	2	5	88
2.36	1.15	116.431	64.7	67.51	1.57	3.13	0	1	4	2	5	88
2.38	1.16	118.47	65.05	67.89	1.57	3.17	0	1	4	2	5	88
2.4	1.17	120.523	65.54	68.41	1.57	3.14	0	0	4	2	5	88
2.42	1.18	122.59	66.07	68.97	1.57	3.13	0	0	4	2	5	88
2.44	1.19	124.671	66.6	69.53	1.57	3.17	0	1	4	3	5	87
2.46	1.2	126.767	67.05	69.99	1.57	3.17	0	1	4	3	6	87
2.48	1.22	128.876	67.49	70.46	1.57	3.19	0	0	4	4	4	87
2.5	1.23	130.999	67.94	70.92	1.57	3.19	0	1	4	3	5	88
2.52	1.24	133.136	68.35	71.34	1.57	3.14	0	0	4	3	5	88
2.54	1.25	135.287	68.72	71.71	1.57	3.16	0	0	4	3	5	88
2.56	1.27	137.451	69.13	72.13	1.57	3.16	0	1	4	3	6	87
2.58	1.28	139.63	69.53	72.54	1.57	3.15	0	0	4	3	5	88
2.6	1.29	141.822	69.94	72.96	1.57	3.18	0	1	4	3	5	88
2.62	1.3	144.027	70.35	73.37	1.57	3.14	0	0	4	3	4	89
2.64	1.32	146.246	70.76	73.79	1.57	3.14	0	1	4	2	5	88
2.66	1.33	148.479	71.17	74.2	1.57	3.16	0	1	4	3	5	87
2.68	1.34	150.725	71.58	74.62	1.57	3.15	0	1	4	2	5	88
2.7	1.36	152.985	71.92	74.96	1.57	3.16	0	0	4	2	5	88
2.72	1.37	155.258	72.13	75.18	1.57	3.2	0	1	4	3	6	87
2.74	1.37	157.545	73.52	76.58	1.57	3.15	0	1	4	3	6	86
2.76	1.36	159.845	74.96	78.03	1.57	3.18	0	1	4	4	7	84
2.78	1.36	162.158	76.21	79.28	1.57	3.16	0	1	4	4	7	85
2.8	1.37	164.484	76.65	79.74	1.57	3.17	0	1	4	5	7	84
2.82	1.38	166.824	77.09	80.19	1.57	3.17	0	1	4	4	7	84
2.84	1.39	169.177	77.54	80.64	1.57	3.16	0	1	4	4	7	84
2.86	1.4	171.543	77.98	81.1	1.57	3.13	0	1	4	4	6	85
2.88	1.42	173.922	78.42	81.55	1.57	3.13	0	1	4	3	7	85
2.9	1.43	176.315	78.87	82	1.56	3.15	0	1	4	4	6	85
2.92	1.44	178.72	79.31	82.46	1.56	3.14	0	1	4	3	6	86
2.94	1.45	181.138	79.75	82.91	1.56	3.17	0	1	4	4	7	85
2.96	1.46	183.57	80.2	83.36	1.56	3.12	0	1	4	3	6	87

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
2.98	1.48	186.014	80.64	83.82	1.56	3.16	0	1	4	2	7	86
3	1.49	188.471	81.08	84.27	1.56	3.16	0	1	4	2	7	86
3.02	1.5	190.941	81.78	84.98	1.56	3.14	0	1	4	2	6	87
3.04	1.5	193.424	82.73	85.93	1.56	3.12	0	1	4	2	6	86
3.06	1.5	195.92	83.68	86.89	1.56	3.16	0	1	4	3	7	85
3.08	1.5	198.429	84.63	87.85	1.56	3.14	0	1	4	3	7	85
3.1	1.51	200.95	85.58	88.81	1.56	3.17	0	1	4	3	8	85
3.12	1.51	203.484	86.53	89.77	1.56	3.11	0	1	4	3	7	85
3.14	1.52	206.031	87.25	90.5	1.56	3.15	0	1	4	4	8	84
3.16	1.54	208.59	87.41	90.67	1.55	3.12	0	1	4	4	7	85
3.18	1.55	211.162	87.58	90.84	1.55	3.12	0	1	4	3	6	86
3.2	1.57	213.747	87.75	91.02	1.55	3.11	0	1	4	3	6	87
3.22	1.59	216.344	87.91	91.19	1.55	3.16	0	1	4	4	6	86
3.24	1.6	218.953	88.08	91.36	1.55	3.15	0	1	4	3	6	86
3.26	1.62	221.576	88.22	91.51	1.55	3.16	0	1	4	3	6	87
3.28	1.64	224.21	88.35	91.65	1.55	3.13	0	1	4	2	5	89
3.3	1.66	226.857	88.48	91.79	1.55	3.15	0	1	4	2	5	89
3.32	1.67	229.517	88.61	91.93	1.55	3.15	0	1	4	2	4	89
3.34	1.69	232.189	88.74	92.07	1.55	3.14	0	1	4	1	4	90
3.36	1.71	234.873	88.87	92.2	1.55	3.14	0	1	4	1	4	90
3.38	1.73	237.57	89	92.34	1.55	3.11	0	1	4	0	3	92
3.4	1.74	240.278	89.13	92.48	1.55	3.11	0	0	4	0	3	92
3.42	1.76	243	89.26	92.62	1.55	3.12	0	0	4	0	3	92
3.44	1.78	245.733	89.38	92.75	1.55	3.14	0	0	4	1	3	91
3.46	1.8	248.479	89.51	92.89	1.55	3.15	0	0	4	1	3	91
3.48	1.81	251.236	89.64	93.03	1.55	3.15	0	0	4	1	3	91
3.5	1.83	254.006	89.77	93.17	1.55	3.14	0	0	4	1	3	92
3.52	1.85	256.788	89.9	93.31	1.55	3.11	0	0	4	0	2	93
3.54	1.87	259.583	90.03	93.44	1.55	3.1	0	0	4	0	2	93
3.56	1.88	262.389	90.16	93.58	1.55	3.11	0	0	4	0	2	93
3.58	1.9	265.207	90.29	93.72	1.55	3.13	0	0	4	1	2	93
3.6	1.92	268.038	90.41	93.86	1.55	3.13	0	0	5	1	1	93
3.62	1.93	270.88	90.54	93.99	1.55	3.14	0	0	5	1	1	93
3.64	1.95	273.734	90.67	94.13	1.55	3.14	0	0	5	1	1	93
3.66	1.97	276.601	90.8	94.27	1.55	3.1	0	0	5	0	1	94
3.68	1.99	279.479	90.93	94.41	1.55	3.1	0	0	5	0	1	94
3.7	2	282.369	91.06	94.55	1.55	3.11	0	0	5	0	1	94
3.72	2.02	285.271	91.19	94.68	1.55	3.11	0	0	5	0	1	94
3.74	2.04	288.185	91.32	94.82	1.55	3.13	0	0	5	1	1	93
3.76	2.05	291.111	91.45	94.96	1.55	3.14	0	0	5	1	1	93
3.78	2.07	294.048	91.57	95.1	1.55	3.15	0	0	5	1	1	93
3.8	2.09	296.997	91.7	95.23	1.55	3.11	0	0	5	0	1	94
3.82	2.11	299.959	91.83	95.37	1.55	3.12	0	0	5	0	1	94
3.84	2.12	302.931	91.96	95.51	1.55	3.1	0	0	5	0	1	94
3.86	2.14	305.916	92.16	95.72	1.55	3.13	0	0	4	1	1	93
3.88	2.14	308.912	92.74	96.31	1.55	3.15	0	0	4	1	2	92
3.9	2.15	311.92	93.33	96.9	1.55	3.1	0	0	5	1	1	93
3.92	2.16	314.94	93.91	97.49	1.55	3.1	0	0	5	1	1	93
3.94	2.16	317.971	94.5	98.09	1.55	3.11	0	0	4	1	2	92
3.96	2.17	321.014	95.08	98.68	1.56	3.11	0	0	4	1	2	92
3.98	2.18	324.068	95.67	99.27	1.56	3.15	0	0	4	2	3	90
4	2.18	327.134	96.25	99.86	1.56	3.16	0	0	4	2	3	90
4.02	2.19	330.211	96.84	100.46	1.56	3.17	0	0	4	2	4	90
4.04	2.2	333.3	97.43	101.05	1.56	3.13	0	0	4	2	3	90
4.06	2.2	336.401	98.01	101.64	1.56	3.15	0	0	4	2	4	89
4.08	2.21	339.513	98.6	102.24	1.56	3.15	0	0	4	2	4	89

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
4.1	2.22	342.636	99.18	102.83	1.56	3.19	0	0	4	3	5	88
4.12	2.22	345.771	99.82	103.47	1.56	3.18	0	0	4	3	5	88
4.14	2.23	348.917	100.46	104.12	1.56	3.13	0	0	4	2	4	88
4.16	2.24	352.075	101.09	104.76	1.56	3.14	0	0	4	2	4	88
4.18	2.24	355.244	101.73	105.4	1.56	3.11	0	0	4	2	5	88
4.2	2.25	358.424	102.36	106.05	1.56	3.14	0	0	4	3	5	88
4.22	2.25	361.616	103	106.69	1.56	3.13	0	0	4	3	6	87
4.24	2.26	364.818	103.64	107.33	1.56	3.13	0	0	4	3	6	87
4.26	2.27	368.033	104.27	107.98	1.56	3.11	0	0	4	3	5	87
4.28	2.27	371.258	104.91	108.62	1.56	3.1	0	0	4	3	5	87
4.3	2.28	374.495	105.55	109.27	1.56	3.15	0	0	4	3	6	87
4.32	2.29	377.743	106.18	109.91	1.56	3.14	0	0	4	3	6	87
4.34	2.29	381.002	106.82	110.55	1.56	3.15	0	0	4	3	6	87
4.36	2.3	384.273	107.45	111.2	1.56	3.11	0	0	4	3	5	87
4.38	2.3	387.554	108.09	111.84	1.56	3.11	0	0	4	3	5	87
4.4	2.31	390.847	108.73	112.48	1.56	3.14	0	0	4	3	6	87
4.42	2.32	394.151	109.24	113	1.56	3.13	0	0	4	3	5	87
4.44	2.33	397.466	109.75	113.52	1.56	3.15	0	1	4	3	6	87
4.46	2.34	400.792	110.26	114.04	1.55	3.14	0	1	4	3	5	88
4.48	2.35	404.129	110.76	114.55	1.55	3.12	0	0	4	2	4	88
4.5	2.36	407.477	111.27	115.07	1.55	3.11	0	0	4	2	4	88
4.52	2.37	410.836	111.78	115.58	1.55	3.15	0	1	4	3	5	88
4.54	2.38	414.207	112.29	116.1	1.55	3.15	0	1	4	2	5	88
4.56	2.38	417.588	112.8	116.61	1.55	3.13	0	0	4	2	4	89
4.58	2.39	420.98	113.3	117.13	1.55	3.14	0	0	4	2	4	88
4.6	2.4	424.383	113.81	117.64	1.55	3.18	0	1	4	2	5	88
4.62	2.41	427.798	114.24	118.08	1.55	3.15	0	0	4	2	4	89
4.64	2.43	431.223	114.33	118.17	1.55	3.15	0	0	5	2	4	89
4.66	2.45	434.659	114.41	118.27	1.55	3.16	0	0	5	2	4	89
4.68	2.47	438.106	114.5	118.37	1.55	3.16	0	0	5	2	3	90
4.7	2.49	441.563	114.59	118.47	1.55	3.15	0	0	5	2	3	90
4.72	2.5	445.032	114.68	118.57	1.55	3.15	0	0	5	1	2	91
4.74	2.52	448.512	114.77	118.67	1.55	3.15	0	0	5	1	2	91
4.76	2.54	452.002	114.86	118.77	1.55	3.15	0	0	5	1	2	91
4.78	2.56	455.503	114.95	118.87	1.55	3.15	0	0	5	1	2	92
4.8	2.58	459.015	115.04	118.97	1.55	3.15	0	0	5	1	2	92
4.82	2.59	462.538	115.13	119.07	1.55	3.15	0	0	5	1	2	92
4.84	2.61	466.071	115.22	119.17	1.55	3.14	0	0	5	1	1	93
4.86	2.63	469.616	115.31	119.27	1.55	3.16	0	0	5	1	1	93
4.88	2.65	473.171	115.4	119.37	1.55	3.15	0	0	5	1	1	93
4.9	2.67	476.736	115.49	119.47	1.55	3.18	0	0	5	1	1	93
4.92	2.68	480.313	115.58	119.57	1.55	3.18	0	0	5	1	1	93
4.94	2.7	483.9	115.66	119.66	1.55	3.19	0	0	5	1	1	93
4.96	2.72	487.498	115.75	119.76	1.55	3.19	0	0	5	0	1	93
4.98	2.74	491.106	115.84	119.86	1.55	3.2	0	0	5	0	1	93
5	2.76	494.725	115.93	119.96	1.55	3.18	0	0	6	0	0	94
5.02	2.77	498.355	116.01	120.05	1.55	3.18	0	0	6	0	0	94
5.04	2.79	501.995	116.09	120.15	1.55	3.18	0	0	6	0	0	94
5.06	2.81	505.646	116.17	120.24	1.55	3.18	0	0	6	0	0	94
5.08	2.83	509.307	116.26	120.34	1.55	3.19	0	0	6	0	0	94
5.1	2.85	512.979	116.34	120.43	1.55	3.22	0	0	6	0	1	93
5.12	2.86	516.662	116.42	120.52	1.55	3.22	0	0	6	0	1	93
5.14	2.88	520.355	116.5	120.62	1.55	3.2	0	0	6	0	1	93
5.16	2.9	524.058	116.58	120.71	1.55	3.21	0	0	6	0	1	93
5.18	2.92	527.772	116.67	120.81	1.55	3.21	0	0	6	0	1	93
5.2	2.94	531.497	116.75	120.9	1.55	3.18	0	0	6	0	0	94

Maxdepth	Avdepth	Discharge	Width	Perim	AvVel	Vel98%	Dist_FishHT's(%)					
(m)	(m)	(m3/s)	(m)	(m)	(m/s)	(m/s)	SvS	SS	SD	FvS	FS	FD
5.22	2.95	535.232	116.83	121	1.55	3.17	0	0	6	0	0	94
5.24	2.97	538.978	116.91	121.09	1.55	3.17	0	0	6	0	0	94
5.26	2.99	542.734	117	121.18	1.55	3.18	0	0	6	0	0	94
5.28	3.01	546.5	117.08	121.28	1.55	3.17	0	0	6	0	0	94
5.3	3.03	550.277	117.16	121.37	1.55	3.22	0	0	6	0	1	93
5.32	3.04	554.064	117.24	121.47	1.55	3.22	0	0	6	0	1	93
5.34	3.06	557.861	117.33	121.56	1.55	3.22	0	0	6	0	1	93
5.36	3.08	561.669	117.41	121.66	1.55	3.23	0	0	6	0	1	93
5.38	3.1	565.488	117.49	121.75	1.55	3.24	0	0	6	0	1	93
5.4	3.11	569.316	117.57	121.84	1.55	3.22	0	0	6	0	0	94
5.42	3.13	573.155	117.66	121.94	1.56	3.21	0	0	6	0	0	94
5.44	3.15	577.004	117.74	122.03	1.56	3.23	0	0	6	0	1	93
5.46	3.17	580.864	117.82	122.13	1.56	3.24	0	0	6	0	1	93
5.48	3.19	584.734	117.9	122.22	1.56	3.23	0	0	6	0	1	93
5.5	3.2	588.614	117.98	122.32	1.56	3.27	0	0	6	1	1	92
5.52	3.22	592.504	118.07	122.41	1.56	3.26	0	0	6	1	1	92
5.54	3.24	596.405	118.15	122.5	1.56	3.25	0	0	6	1	1	92
5.56	3.26	600.316	118.23	122.6	1.56	3.26	0	0	6	1	1	92
5.58	3.27	604.237	118.31	122.69	1.56	3.26	0	0	6	0	1	92
5.6	3.29	608.168	118.4	122.79	1.56	3.24	0	0	6	0	1	93
5.62	3.31	612.109	118.48	122.88	1.56	3.24	0	0	6	0	1	93
5.64	3.33	616.061	118.56	122.98	1.56	3.25	0	0	6	0	0	93
5.66	3.35	620.023	118.64	123.07	1.56	3.25	0	0	6	0	0	93
5.68	3.36	623.995	118.73	123.16	1.56	3.25	0	0	6	0	0	93
5.7	3.38	627.977	118.81	123.26	1.56	3.27	0	0	6	0	1	92
5.72	3.4	631.969	118.89	123.35	1.56	3.27	0	0	6	0	1	92
5.74	3.42	635.971	118.97	123.45	1.56	3.27	0	0	6	0	1	92
5.76	3.43	639.984	119.05	123.54	1.57	3.28	0	0	6	0	1	92
5.78	3.45	644.006	119.14	123.63	1.57	3.25	0	0	6	0	0	93
5.8	3.47	648.039	119.22	123.73	1.57	3.25	0	0	6	0	0	93
5.82	3.49	652.082	119.3	123.82	1.57	3.26	0	0	6	0	0	93
5.84	3.5	656.134	119.38	123.92	1.57	3.26	0	0	6	0	0	93
5.86	3.52	660.197	119.47	124.01	1.57	3.27	0	0	6	0	0	93
5.88	3.54	664.27	119.55	124.11	1.57	3.31	0	0	6	0	1	92
5.9	3.56	668.353	119.63	124.2	1.57	3.3	0	0	6	0	1	92
5.92	3.57	672.445	119.71	124.29	1.57	3.3	0	0	6	0	1	92
5.94	3.59	676.548	119.8	124.39	1.57	3.31	0	0	6	0	1	92
5.96	3.61	680.661	119.88	124.48	1.57	3.31	0	0	6	0	1	92
5.98	3.63	684.784	119.96	124.58	1.57	3.28	0	0	6	0	0	93
6	3.64	688.916	120.04	124.67	1.57	3.28	0	0	6	0	0	93

SvS=Slow very Shallow; SS=Slow Shallow; SD=Slow Deep; FvS=Fast very Shallow; FS=Fast Shallow; FD=Fast Deep (for velocity and depth ranges refer to Birkhead 2010)

4 WATER QUALITY

4.1 Introduction

4.1.1 Objectives of the water quality discipline

The main objective of the water quality study was to identify the relationship between water quality and flow level changes, and to predict what impacts, if any, will occur with changes to the present day flow regimes.

4.1.2 Assumptions and limitations

The following assumptions and limitations apply:

- There is currently no official method to determine the water quality component of the Ecological Reserve. There have also been changes as the method evolved; for example, Ecological Categories were previously defined in 6 categories A-F; redefined as 4 categories Natural, Good, Fair, Poor; and then changed to five ratings (Ratings 0 – 5). There is an urgent need to finalise the water quality reserve assessment method. The DRAFT Physico-chemical Assessment Index (PAI) is currently the latest version, albeit it is incomplete (DWAF 2008) and was used.
- The PAI method is based on data lodged in the WMS database. Water quality monitoring stopped in 2017/18 due to budget constraints so these were the data available and were used.
- There were no medium to long-term observed data for water temperature, clarity/turbidity/suspended sediments, or dissolved oxygen. Once off temperature and Dissolved Oxygen measurements were taken on the fish and invertebrate data collection field trips and there were some temperature data in the Freshwater Biodiversity Information System (Dallas & Rivers-Moore (2019).

4.2 EWR sites with a focus on water quality

4.2.1 Catchment description

The description of the water quality status of the Limpopo Basin is a summary of that described in the Delineation and Status Quo Report for this study. The water quality categories “Ideal”, “Acceptable”, “Tolerable” and “Unacceptable” were used to describe the water quality status. These terms are defined in DWAF (2011) and describe the fitness for use ranging from ideal with no impacts on any water uses, to unacceptable for a quality where the water becomes unfit for most uses (**Table 4.1**).

4.2.1.1 Lephalala River in Secondary Catchment A5

The current surface water quality of the Lephalala River was either acceptable or ideal with the exception of pH, Orthophosphates and sulphates which were unacceptable. The land use of the Lephalala River is mainly agriculture. Witpoort is a small town where the wastewater treatment was not operating efficiently. The Lephalala River had a deteriorating water quality trend due to agricultural runoff and mining activities in the catchment.

Water quality in the upper third of the Lephalala River (recorded at A5H004Q01, Lephalala at Muisvogelkraal, A50B quaternary), just upstream of 1_Lephalala were very good and in an Ideal category for all the constituents assessed. Occasional (< 5% of the time) elevated Orthophosphate concentrations were observed in an Acceptable category. At the Susandale sampling point (A50G

quaternary), upstream of the Susandale Dam, water quality was in an Ideal category except for Orthophosphate that was classified as Unacceptable. However, this was an anomaly of the water testing laboratory that had a lower detection limit of 0.2 mg/l. Just downstream of that water tests at RQIS found that PO4-P concentrations is in an Ideal category for rivers. In the lower reaches at sampling point A5H008Q01 (Ga-Seleka Village Bossche Diesch 53 LQ R572 Bridge) (A50H quaternary) water quality was Ideal for the parameters assessed although elevated Orthophosphate concentrations were observed from time to time that fell within Acceptable (75th percentile) or Unacceptable (95th percentile) categories. This could be due to agricultural return flows, domestic wastewater discharges and/or runoff from villages near the lower Lephalala River.

Table 4.1: Water quality categories and its relationship to the South African Water Quality Guidelines (DWAF. 2011)

Fitness for use category	User category and effect			
	Aquatic Ecosystems	Domestic	Recreation	Agriculture
Ideal	Upper limit of TWQR. No impact expected on all species.	Upper limit of TWQR. No health risk. No aesthetic effect.	Upper limit of TWQR. No health risk. No aesthetic effect.	Upper limit of TWQR. No reduction in yield. No special management practices.
Acceptable	Average of TWQR and Chronic Effect Value (CEV). Some chronic effects may occur in sensitive species.	Average of TWQR and Tolerable level. Slight health risk for sensitive individuals. Noticeable aesthetic effect but not objectionable.	Average of TWQR and Tolerable level. Slight health risk for sensitive individuals. Noticeable aesthetic effect, but acceptable.	Average of TWQR and Tolerable level. Only sensitive crops are affected, but no special management practices are required.
Tolerable	Upper limit of CEV. Some acute effects may occur in sensitive species.	At Tolerable level / minimal health risk. Slight health risk for most individuals. Objectionable aesthetic effect to sensitive persons.	At Tolerable level / minimal health risk. Slight health risk for most individuals. Objectionable aesthetic effect to sensitive persons.	At Tolerable level / minimal health risk. Some yield loss is experienced or special management practices are required.
Unacceptable	Above the CEV. Species diversity is significantly reduced, and community as a whole is com-promised.	Above Tolerable level. Significant health risk with short-term exposure. Aesthetically un-acceptable.	Above Tolerable level. Severe health risk. Aesthetically unacceptable.	Above Tolerable level. The economic viability of irrigation is questionable.
Totally unfit for use	Gross pollution or deviation from the normal conditions.			

Note - TWQR = Target water quality range, CEV = Chronic effect value

Water quality in the Vischgat Dam (A5R001Q01) (A50E quaternary) and the Susandale Dam (A5R002Q01) (A50H quaternary) were in a very good state with respect to all the parameters that were assessed except for Orthophosphate concentrations and pH values greater than 8 being observed occasionally. The median Orthophosphate concentrations were in an Acceptable category, but occasionally (95th percentile) elevated P concentrations were observed that fell within an Unacceptable category for dams. This implied that short duration algal blooms may develop when the other growth controlling factors such as water temperature and water clarity were favourable. These dams were not

part of the National Eutrophication Monitoring Programme and no chlorophyll data existed for them to assess their actual trophic status.

4.2.1.2 Mogalakwena River in Secondary Catchment A6

The drivers of water quality in this catchment were the towns of Modimolle, Dimune, Nylsvley, Mokopane and Mookgophong all of which had the challenges of wastewater treatment works (WWTWs). Furthermore, there were large platinum mines in the upper catchment with nitrate problems from blasting as well as seasonal elevated turbidity levels from runoff from mining activities. Glen Alpine Dam was used for commercial agriculture of potatoes and tomatoes.

Salinity in the upper Mogalakwena catchment (A61A) (A6H006Q01, A6H011Q01, and A6H018Q01) was in an Ideal category for most of the constituents evaluated. The median Orthophosphate concentrations were in an Ideal category, but slightly elevated concentrations (Acceptable category) were measured from time to time. High salinity, unionised ammonia, nitrogen and Orthophosphates were recorded downstream of the Modimolle WWTW at the PHAGAMENG sampling point. This supports finding of various studies stating the WWTW was not complying with effluent discharge standards. Water quality in the A61B catchment (A6H002Q01, A6H012Q01, A6H019Q01 and A6H020Q01) was mostly in an Ideal category although slightly elevated Orthophosphates have been recorded in the catchment. This could have been due to minor irrigation return flows. In the A61C catchment at sampling point A6H037, elevated salts, unionised ammonia and orthphospates were measured. On average concentrations were in an Ideal category but occasional elevated concentrations took it into Tolerable/Unacceptable categories. It was not clear why this should be the case as this sampling point at Vogelfontein falls within the Nylsvley wetland. Water quality in the A61F catchment, in and around Mokopane, was poor with elevated salts, unionised ammonia, and orthphospate concentrations in the Unacceptable category. High sulphate concentrations were also recorded in the Dorps River at SEKGAKGAP. This could have been due to runoff from the industrial area upstream of the sampling point. Water quality in the Pholotsi River downstream of the Mogalakwena platinum mines at sampling point GA-MAPELA was poor with high salts, high orthphospates and high sulphate concentrations, all in an Unacceptable category. Water quality in the lower Mogalakwena River upstream of the Limpopo confluence (A6H035Q01) was mostly in an Acceptable category due to elevated salts, pH values and some elevated orthphospate concentrations.

Water quality in Doorndraai Dam on the Sterk River (A6R001Q01) (A61J quaternary) was in an Ideal category except for Orthophosphate concentrations (95th percentile). The median Orthophosphate concentrations were in an Acceptable category, but occasionally (95th percentile) elevated orthophosphate concentrations were observed that fell within an Unacceptable category for dams. This implied that short duration algal blooms developed when the other growth controlling factors such as water temperature and water clarity were favourable. However, chlorophyll *a* data collected for the National Eutrophication Monitoring Programme (NEMP) indicated that Doorndraai Dam was consistently in an Oligotrophic (unenriched with plant nutrients) state.

In Glen Alpine Dam in the middle reaches of the Mogalakwena River (A6R002Q01) (A62J quaternary) the average water quality was in an Ideal category but elevated salts and nutrients were observed. pH was mostly in an Acceptable category (> 8 pH units) for most of the time but on occasion pH values greater that 8.5 pH units were observed. Elevated Orthophosphate concentrations were observed in the

dam with median concentrations falling in an Acceptable category, 75th percentile concentration in a Tolerable category and the 95th percentile concentration in an Unacceptable category. The implication was that algal blooms could occur regularly in Glen Alpine Dam. Chlorophyll *a* data collected for the NEMP indicate that for at least 75% of the time the dam was in an Oligotrophic state, but occasionally the dam may be in a Mesotrophic (moderately enriched with plant nutrients) state.

4.2.1.3 Sand River in Secondary Catchment A7

In general, water quality in the A7 catchment was impacted by effluent from WWTWs in the area. There were also many areas of sand and aggregate mining in the A7 catchment, brick making factories and one silica mine and factory. However, there were no coal mining activities in the catchment. There were also intensive agricultural activities near the rivers which could contribute to the nutrient levels in the river.

The water quality sampling points in the A71A catchment were located on the Sand River and Bloed Rivier within the urban areas of Polokwane and Seshego. Their water quality therefore reflected the impacts of urban runoff, agricultural return flows upstream of Polokwane, and perhaps the Witkop Silica Mine. The mine was some distance away from the Sand River on the watershed with the A71B catchment. At many of these sampling points high salts were recorded, high orthphospate concentrations and elevated pH values were often in Unacceptable categories. High unionised ammonia concentrations were also recorded in the Sand and Bloed Rivier. At A7H010Q01 in the A71H catchment near 7_Sand, water quality was mostly in an Ideal category and slightly elevated orthphospate and pH values occasionally took the Sand River into an Acceptable category. The lower reaches of the Sand River were poorly monitored with most sampling points located downstream of WWTW outflows. Sampling at A7H005Q01 stopped in 1981, probably in response to the non-perennial nature of the lower reaches.

There were no dams in the Sand River secondary catchment where the DWS monitors in-lake water quality.

4.2.1.4 Nzhelele River in Secondary Catchment A8

The water quality status in the A80 catchment was impacted in the upper reaches by urban sprawl, subsistence agriculture, and sand mining and the water quality challenges that these land use activities pose. In the large dams in the middle reaches the wide seasonal fluctuations were diminished resulting in a constant quality of water released to downstream irrigation users.

In catchment A80B of the Nzhelele River, at HA-RABALI (Nzhelele at Ha-Rabali, at Dzanani to Rabali Road Bridge), water quality was in a poorer state. Salts were elevated in Acceptable and Tolerable categories, elevated pH values occurred (Unacceptable category) and elevated orthphospate concentrations were recorded (median in an Acceptable category, 95th percentile in an Unacceptable category). Here the Nzhelele River was surrounded by villages and subsistence agriculture up to the edge of the river. Grey water runoff and agricultural seepage could account for the elevated salt and nutrient concentrations in the rivers. From there the river flows through the mountain into Nzhelele Dam. The water quality of the outflow from Nzhelele Dam was in an Ideal category except for slightly elevated pH values (Acceptable category). There were no further water quality sampling points on the Nzhelele

River downstream of the Mutamba River confluence where any long-term data record existed. There were several citrus irrigation schemes near the river that received irrigation water from Nzhelele Dam.

In the Ṅwaneḍi River (A80H and A80J) water quality monitoring was poor. The only good monitoring points were located at Ṅwaneḍi Dam and Luphephe Dam or their downstream weirs. Other registered sampling points mostly had one or a few samples collected. The catchment downstream of the two dams was poorly monitored up to confluence with the Limpopo River.

In Mutshedzi Dam on the Mutshedzi River (A8R004Q01) water quality was in an Ideal category except for elevated orthphospate concentrations that were generally in an Acceptable category although high concentrations in the Unacceptable category occurred infrequently. Chlorophyll *a* data collected for the NEMP indicated that Mutshedzi Dam was mostly in an Oligotrophic state (unenriched with plant nutrients) but occasionally in a Mesotrophic state (moderately enriched). The potential for short term algal blooms existed due to elevated orthphospate concentrations.

Water quality in Nzhelele Dam on the Nzhelele River (A8R001Q01) had elevated salt concentrations in an Acceptable category, elevated pH values in Acceptable/Tolerable categories and elevated orthphospate concentrations, mostly in an Acceptable category but infrequently elevated to an Unacceptable category. Chlorophyll *a* data collected for the NEMP indicate that Nzhelele Dam was consistently in an Oligotrophic state (unenriched with nutrients). The potential for short term algal blooms existed due to elevated orthphospate concentrations.

Luphephe Dam on the Luphephe River (A8R002Q01) generally had good water quality (Ideal category) with low salinity although elevated orthphospate concentrations have been observed that were classified in an Acceptable category with high concentrations occurring from time to time. Chlorophyll *a* data collected for the NEMP indicated that Luphephe Dam was consistently in an Oligotrophic state (unenriched with nutrients). The potential for short term algal blooms existed due to elevated orthphospate concentrations.

Ṅwaneḍi Dam on the Ṅwaneḍi River (A8R003Q01) was in a similar water quality state as Luphephe Dam. Chlorophyll *a* data collected for the NEMP indicated that Ṅwaneḍi Dam was in an Oligotrophic state for at least 50% of the time, but for 25% of the time was in a Mesotrophic state, and from time-to-time algal blooms occurred that were characteristic of Hypertrophic conditions (highly enriched with nutrients).

4.2.1.5 Luvuvhu River in Secondary Catchment A9

The water quality status of the Luvuvhu River was driven by intensive agriculture of sub-tropical fruits and afforestation in the upper catchment, the urban sprawl of Thohoyandou in the middle catchment and the KNP in the lower end of the catchment. The water quality trends in the middle to lower Luvuvhu River indicated a deterioration of the orthphospates, nitrates and ammonia levels. This deterioration in water quality was a result of the intense agriculture and domestic wastes associated with Thohoyandou and the un-serviced intense dense settlements upstream of the KNP. The Luvuvhu River was subject to ongoing research into the human health and fish impacts associated with the use of DDT for malaria control in the catchment.

The water quality monitoring points in the upper Luvuvhu River catchment (A91A Luvuvhu River and A91B Doringspruit River) have insufficient data records to assess the water quality in these catchments. Water quality in the Doringspruit River was expected to be impacted by urban runoff from Elim and effluent from the Elim hospital WWTW. The two rivers flow into Albasini Dam. Water quality in the middle reaches of the Latonyanda River (A91D) at A9H027, was in an Ideal category for all the parameters assessed. The 95th percentile for orthphospates fell within the Acceptable category. This sampling point was located upstream of the villages of Tshakhuma and Mulangaphuma, and the irrigation schemes. There was no further sampling point up to the confluence with the Luvuvhu River where recent data (2008-2018) was available. Water quality in this river reach could be affected by urban runoff and irrigation return flows.

The median water quality in the outflow from Albasini Dam (A9H020Q01) was in an Ideal category but elevated salts in the Acceptable category were observed infrequently, and elevated orthphospate concentrations in the Unacceptable category (95th percentile). There were no sampling points in the Luvuvhu River from downstream of the Albasini Dam (A91C) up the confluence with the Latonyanda River (A91D).

At the Luvuvhu sampling point KA-HASANE just upstream of the inflow into Nanḓoni Dam, the median water quality was in an Ideal category except for salts which could increase to a Tolerable category and elevated orthphospate concentrations (Acceptable & infrequent Unacceptable categories). The outflow from Nanḓoni Dam at A9H030Q01, showed the median water quality to be in an Ideal category but with occasional high salts (Acceptable category) and elevated orthphospate concentrations (Acceptable and Unacceptable categories).

In the Mutshinduḓi River (A91G) at the Vonḓo Dam outflow, A9H026Q01, the median and 95th percentile water quality was in an Ideal category although slightly elevated orthphospate concentrations (Acceptable category) occurred from time-to-time. At A9H002Q01 (Mutshinduḓi River at Sibasa), just upstream of the confluence with the Tshinane River, water quality was in an Ideal category. Water quality in the Tshinane River at A9H003Q01 was in an Ideal category with infrequent elevated orthphospates (Acceptable category). In the Mutshinduḓi River upstream of the Luvuvhu confluence, at sampling point A9H025, water quality was in an Ideal category for all the constituents assessed.

In the Lower Luvuvhu (A91H to A92D), upstream of 12_Luvuvhu, at sampling point A9H012Q01 (Luvuvhu River at Mhinga) water quality was in an Ideal category for all the constituents assessed although elevated orthphospates in the Acceptable category were recorded infrequently. At sampling point A9H008Q01 (Luvuvhu River at Shidzivane/Kruger National Park) water quality was in an Ideal category for all the constituents assessed although elevated orthphospates in the Acceptable category were recorded infrequently.

Water quality monitoring in the Mutale River catchment (A92A-D) was poor with most sampling points concentrated in the upper reaches of the A92A catchment. Water quality in the upper Mutale was in an Ideal category except for elevated orthphospate concentrations (median Acceptable and 95th percentile in an Unacceptable category). Elevated orthphospate concentrations were also recorded at TSHANDAMA sampling point, on the border with the A92B catchment. At the SANARI VI sampling point, water quality was in an Ideal category for salts but for elevated orthphospate concentrations (median Acceptable and 95th percentile in an Unacceptable category). In the Mutale River just upstream of the

confluence with the Luvuvhu River at sampling point A9H013Q01, water quality was in ideal category and only slightly elevated orthphospate concentrations were recorded in an Acceptable category.

In the Luvuvhu River at Pafuri/Kruger National Park (A91K) at sampling point A9H011Q01 water quality was in ideal category and only slightly elevated orthphospate concentrations were recorded in an Acceptable category.

Water quality in Albasini Dam on the Luvuvhu River (A9R001Q01) in terms of salinity was mostly in an Ideal category and sometimes in an Acceptable category. Elevated pH values in the Acceptable and Tolerable category were recorded in the dam. Chlorophyll *a* data collected for the NEMP indicated that Albasini Dam was consistently in an Oligotrophic state (unenriched with plant nutrients). The potential for short term algal blooms existed due to elevated orthphospate concentrations.

At Vondo Dam on the Mutshinduḍi River (A9R002Q01) water quality was in an Ideal category for all the constituents assessed except for orthphospate concentrations which was in an Acceptable category for most of the time and sometimes in an Unacceptable category. Chlorophyll *a* data collected for the NEMP indicate that Vondo Dam was consistently in an Oligotrophic state (unenriched with plant nutrients). The potential for short term algal blooms existed due to elevated orthphospate concentrations.

At Ṋandoni Dam on the Luvuvhu River (A9R004) water quality was in an Ideal category for all the constituents assessed except for orthphospate concentrations that were in an Acceptable category for most of the time and sometimes in an Unacceptable category. Elevated pH values in the Acceptable category were observed. Chlorophyll *a* data collected for the NEMP indicated that Ṋandoni Dam was consistently in an Oligotrophic state (unenriched with plant nutrients). The potential for short term algal blooms existed due to elevated orthphospate concentrations.

4.2.2 Data collection and analysis

The ecological water quality assessment was based on the “Methods for Determining the Water Quality Component of the Ecological Reserve for Rivers” (DWAF 2008).

Water quality data was obtained from the DWS WMS water quality database. The location of DWS water quality monitoring points in each catchment, the length of the dataset, frequency of sampling and the parameters measured were investigated. The sampling points closest to the EWR sites where a reasonable long term and recent data record existed, were identified to describe the present water quality status. In some catchments there were no water quality sampling points near the EWR sites (**Section 4.2.1**).

The water quality data provided by the Department were prepared for analysis and summary statistics were calculated with Statistica 8 for the period 2008 to 2018. The frequency of water quality sampling was reduced in the mid-2000s and sampling was stopped in 2018 due to severe budget constraints. Sampling was slowly being restored although the frequency was still very low. Water quality data from 2008 - 2018 for electrical conductivity (EC), pH, Orthophosphate, nitrate plus nitrite nitrogen, and ammonium – the latter combined to give Total Inorganic Nitrogen (TIN) - were used in the assessment. For each constituent, summary statistics were calculated which included the 5th percentile, median, and 95th percentile values. For the present status assessment of the nutrients, the median concentrations

were used, for the EC the 95th percentile was used, and for pH the 5th and 95th percentile values were used as per the water quality reserve methodology.

The present state rating values given in **Table 4.2 to Table 4.7** were used to rate the status of individual water quality variables for each sampling point associated with an EWR site. The overall site classification for water quality at each EWR site was obtained using the PAI EcoStatus model (DWAF 2008).

Table 4.2: Present state rating values for Electrical Conductivity (DWAF 2008)

Description of WQ	A – F category	Rating	Value (mS/m)
Natural	A	0	≤ 30
Good	B	1	30.1 - ≤ 55
Upper fair	C	2	55.1 - ≤ 85
Lower fair	D	3	>85
Poor	E/F	4	-

Table 4.3: Present state rating values for orthphospate (PO_4-P) and Total Inorganic Nitrogen (TIN) used to describe water quality in terms of Category and Rating (DWAF 2008)

Rating	Deviation	Description	PO4-P (mg/L)	TIN-N (mg/L)
0	No change	Natural (Oligotrophic) - pristine river and catchment, no known man-made changes to the nutrient regime, oligotrophic conditions, no visible presence of phytoplankton, thin periphyton mats (<0.5 mm thick), water clear.	<0.005	<0.25
1	Small change	Oligo – mesotrophic – minor modifications to the catchment affecting the nutrient status, phytoplankton barely evident, thin periphyton mats (<0.5 mm thick), water is largely clear. Less than 10% cover with filamentous algae.	0.005 – 0.015	0.25 – 0.70
2	Moderate change	Mesotrophic moderate modifications to the catchment affecting the nutrient status, some evidence of phytoplankton, medium periphyton mats 0.5-3mm thick), short filamentous algae (< 2cm long). 10 - 20% cover with filamentous algae.	0.015 – 0.025	0.70 – 1.0
3	Large change	Eutrophic –visible evidence of phytoplankton and the water appears green, thick periphyton mats (> 3 mm thick), long filamentous algae (> 2cm long). 20 - 50% cover with filamentous algae.	0.025 – 0.125	1.0 – 4.0
4	Serious change	Eutrophic conditions, visible evidence of algal phytoplankton blooms, thick periphyton mats (> 3 mm thick), long filamentous algae (> 5 cm long), periphyton rarely washed away. 50 - 80% cover with filamentous algae.	>0.125	>4.0
5	Extreme change	Hyper-eutrophic conditions are present, low DO and noxious odours, visible evidence of algal scums accumulating in embayments, toxic blue-green algae present or suspected to be present, periphyton <80% cover present most of the time, or long strands of filamentous algae visible. 80 – 95% cover with filamentous algae.		

Table 4.4: Present state rating values for pH (DWAF 2008)

Rating	Deviation	pH (5th percentile)	pH (95th percentile)
0	No change	6.5 to 8.0	6.5 to 8.0
1	Small change	5.9 – 6.5	8.0 – 8.8
2	Moderate change	5.6 – 5.9	8.8 – 9.2
3	Large change	5.0 – 5.6	9.2 – 10.0
4	Serious change	4.0 - 5.0	10.0 – 11.0
5	Extreme change	<4	>11.0

Table 4.5: Present state rating values for dissolved oxygen (DO) (DWAF 2008)

Rating	Deviation	Environmental clues	Concentration (mg/L)
0	No change	Known to be a pristine river, no known problems or concerns about dissolved oxygen; all oxygen sensitive species are present.	> 8
1	Small change	Some man-made modifications in the catchment but no known problems or concerns about DO, most oxygen sensitive species are present.	7 – 8
2	Moderate change	Some concerns about dissolved oxygen, some oxygen sensitive species are present but mostly oxygen tolerant species.	6 – 7
3	Large change	Known problems with reduced dissolve oxygen, mostly low DO tolerant species are present.	4 – 6
4	Serious change	Major known problems with low dissolved oxygen, anoxic odours sometimes present, only very low DO tolerant species present.	2 – 4
5	Extreme change	Extreme concerns about low DO, anoxic odours present most of the time, colour of the water often dark with organic material, benthic algae replaced by grey/black bacterial films and sewage fungus, no biota present most of the time.	0 – 2

Table 4.6: Present state rating values for temperature (DWAF 2008)

Rating	Deviation	Environmental clues about the temperature status	Deviation from the natural monthly temperature range (10th and 90th percentile values)
0	No change	Pristine river, catchment natural, no known problems with temperature. All temperature sensitive species present in abundances and frequencies of occurrence as expected for a reference state.	Natural temperature range, measured or estimated from air temperature
1	Small change	Some minor man-made changes to the river but no known changes to the natural temperature regime. Some highly temperature sensitive species in lower abundance and frequency of occurrence than expected for a reference state.	Natural temperature range, measured or estimated from air temperature
2	Moderate change	Moderate change to temperature, occurs infrequently. Most highly temperature sensitive species in lower abundances and frequency of occurrence than expected for a reference state.	Vary by no more than 2°C
3	Large change	Large change to temperature regime occurs often. Most moderately temperature sensitive species in lower abundances and frequency of occurrence than expected for a reference state.	Vary by no more than 4°C
4	Serious change	Serious changes to temperature regime, occurs most of the time, only biota highly tolerant to temperature changes	Vary by more than 4°C

Rating	Deviation	Environmental clues about the temperature status	Deviation from the natural monthly temperature range (10th and 90th percentile values)
		occur. All moderately temperature sensitive species in much lower abundances and frequency of occurrence than expected for reference. Temperature insensitive species may have high abundances and frequency of occurrence.	
5	Extreme change	Extreme changes to temperature regime, occurs all the time, only biota highly tolerant to temp changes occur. At best, only temperature insensitive species present, often with very low abundances and frequency of occurrence.	Vary by more than 5°C, up to a maximum 30°C for the upper boundary

Table 4.7: Present state rating descriptions for turbidity/clarity (DWAF 2008)

Rating	Deviation	Environmental clues about the turbidity status
0	No change	Pristine river, no known man-made modifications of the catchment, no known concerns about turbidity, changes in turbidity appears to be natural and related to natural catchment processes such as rainfall runoff.
1	Small change	Some minor man-made modifications to the catchment, changes in turbidity appear to be largely natural and related to natural catchment processes such as rainfall runoff. Very minor effects of silting of habitats, largely of a temporary nature, and natural river processes clear newly deposited silt soon after the event.
2	Moderate change	Moderate changes to the catchment land-use have resulted in unnaturally high sediment loads and high turbidity during runoff events. The impacts are however temporary.
3	Large change	Erosion and/or urban runoff processes is a known cause of unnaturally large increases in sediment loads and turbidity, habitat often silted but it is cleared from time to time. Low amounts of periphyton algae or phytoplankton are present.
4	Serious change	The catchment is known to have serious erosion problems, increased turbidity levels are present most of the time, large silt loads are deposited leading to a serious reduction in habitat. Low amounts of periphyton algae or phytoplankton are present.
5	Extreme change	The catchment is known to have serious erosion problems, increased turbidity levels are present most of the time, large silt loads are deposited leading to an almost total loss of habitat, silt loads are so high that fish kills have been attributed to it.

Water temperatures are not routinely recorded in South African rivers. An estimate was made of the reference monthly average water temperatures at each EWR site. The estimate was based on the average monthly air temperatures in FBIS (Freshwater Biodiversity Information System) at the nearest FBIS site, which in turn was calculated from historical air temperature data recorded in South Africa (Schulze & Maharaj 2004). The following equations were used to derive the mean water temperature:

(WT_{mean}) from the mean air temperatures (AT_{mean}) (Dallas & Rivers-Moore 2022).

Upland rivers $WT_{mean} = 6.766 + (0.552*AT_{mean})$

Lowland rivers $WT_{mean} = 3.278 + (0.899*AT_{mean})$

4.2.3 Description of sites

4.2.3.1 1_Lephalala

The closest DWS water quality sampling site was A5H004Q01 (At Muisvogelkraal), where 435 samples have been collected from 1971 to 2018. The data from 2008-2018 were used in the analysis and the summary statistics are presented in Table 4.8. There was a crocodile farm upstream of the EWR site which might affect the nutrient concentrations and dissolved oxygen if they use a flow-through system, or if they wash out the ponds from time to time. Washing out the ponds could contribute to a pulse load of high COD/BOD water that could affect DO until the added organic material has decomposed.

The WQ was in a **B** category (**Table 4.9**).

Table 4.8: Water quality summary statistics for 1_Lephalala

A5H004Q01	N	Mean	Median	Min	Max	25%tile	75%tile	5%tile	95%tile	Std.Dev.
Ca (mg/L)	88	1.572	1.250	0.350	8.200	1.250	1.707	0.500	2.952	1.022
Cl (mg/L)	85	6.268	5.700	3.669	31.600	5.086	6.468	4.178	9.061	3.141
EC (mS/m)	87	4.759	4.400	2.368	17.800	3.850	5.130	3.200	7.300	1.785
Mg (mg/L)	87	0.900	0.750	0.470	2.723	0.750	0.750	0.750	1.800	0.418
NH4-N (mg/L)	88	0.063	0.050	0.025	0.997	0.025	0.050	0.025	0.117	0.137
NO3+NO2-N (mg/L)	88	0.069	0.050	0.005	1.099	0.025	0.050	0.005	0.216	0.132
Na (mg/L)	77	2.911	2.061	0.169	19.600	2.000	3.700	0.440	5.898	2.427
PO4-P (mg/L)	88	0.011	0.010	0.005	0.081	0.005	0.010	0.005	0.030	0.011
SO4 (mg/L)	85	1.458	1.500	0.375	5.100	0.600	1.500	0.375	3.000	0.947
pH (pH units)	90	7.022	7.028	4.835	8.707	6.840	7.200	6.500	7.597	0.413

Table 4.9: PAI results for 1_Lephalala

IUA	Upper Lephalala	Water quality points	
River & Quat	Lephalala (A50B)	RC	Default boundary tables
EWR site	1_Lephalala	PES	A5H004Q01 (2008-2018) n=87
Confidence assessment	Moderate – High		
Water quality constituents		PES value	Category (Rating)
Nutrients	PO_4-P (mg/l) median	0.010	1
	TIN (mg/l) median	0.100	0
Physical variables	pH	6.5 – 7.6	0
	T (°C) May 2023	22.38 C	1
	DO (mg/l) May 2023	(8.7 mg/l / 111.3%)	1
	Turbidity (NTU)	No data	1
	EC mS/m	7.30	0
Response variables	Macroinvertebrate (ASPT) score	6.0	
Overall site classification (from PAI)		**B** (84.5%)	

Time series plots of EC, NO_2+NO_3-N and PO_4-P indicate a slight negative (increasing) trend (2008-2018) (**Figure 4.1**).

There is no relationship between flow and EC, nutrients and pH at 1_Lephala. Concentrations are slightly elevated at low flows (**Figure 4.2**).

Average monthly water temperatures (°C) at 1_Lephalala are given in **Table 4.10**.

Table 4.10: Average water temperatures at 1_Lephalala

Calendar month											
J	F	M	A	M	J	J	A	S	O	N	D
20.6	20.0	19.5	17.8	15.6	14.5	14.5	15.6	17.8	19.5	20.0	20.0

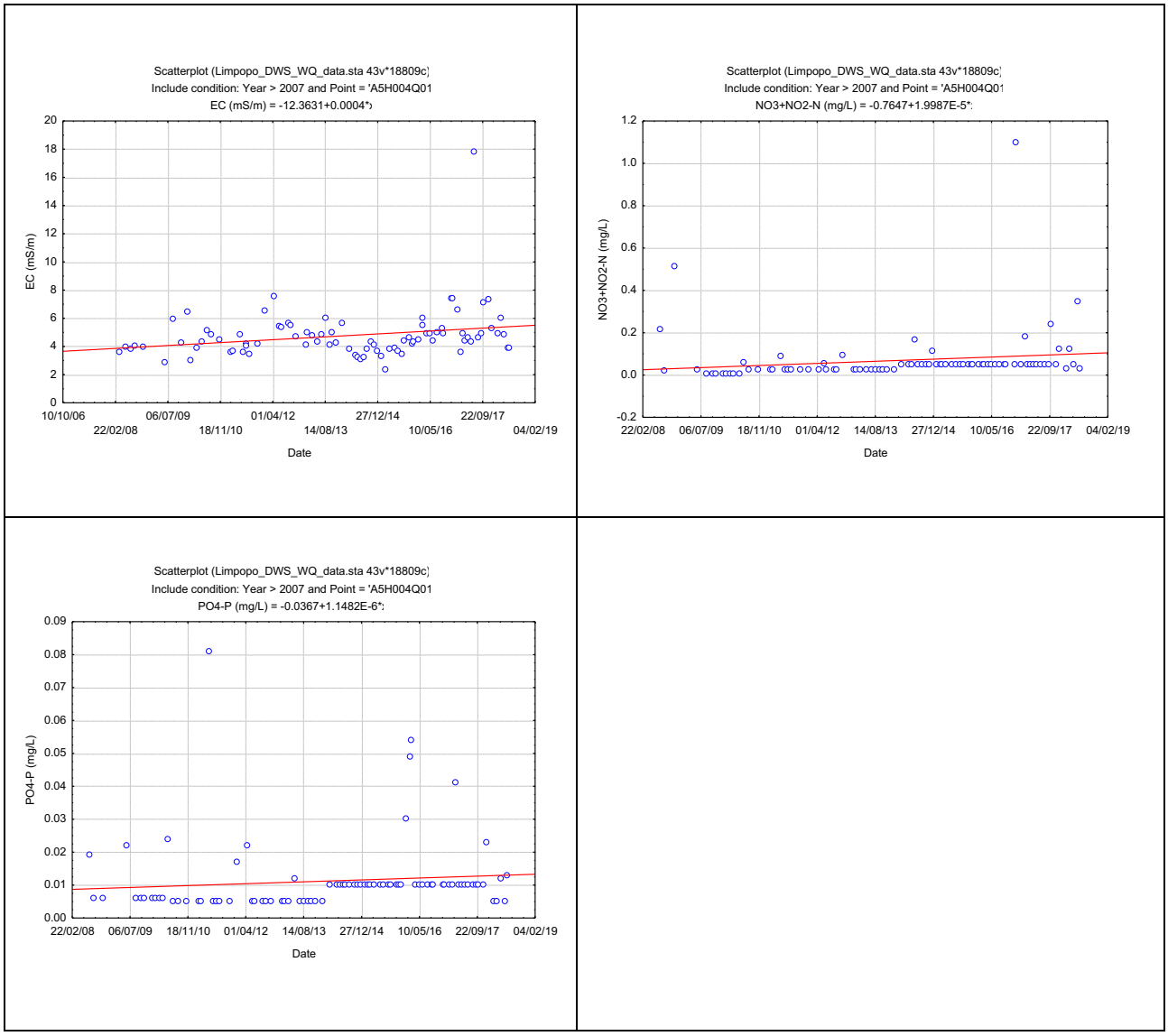


Figure 4.1: Time series plots of EC, NO_2+NO_3-N and PO_4-P at 1_Lephalala

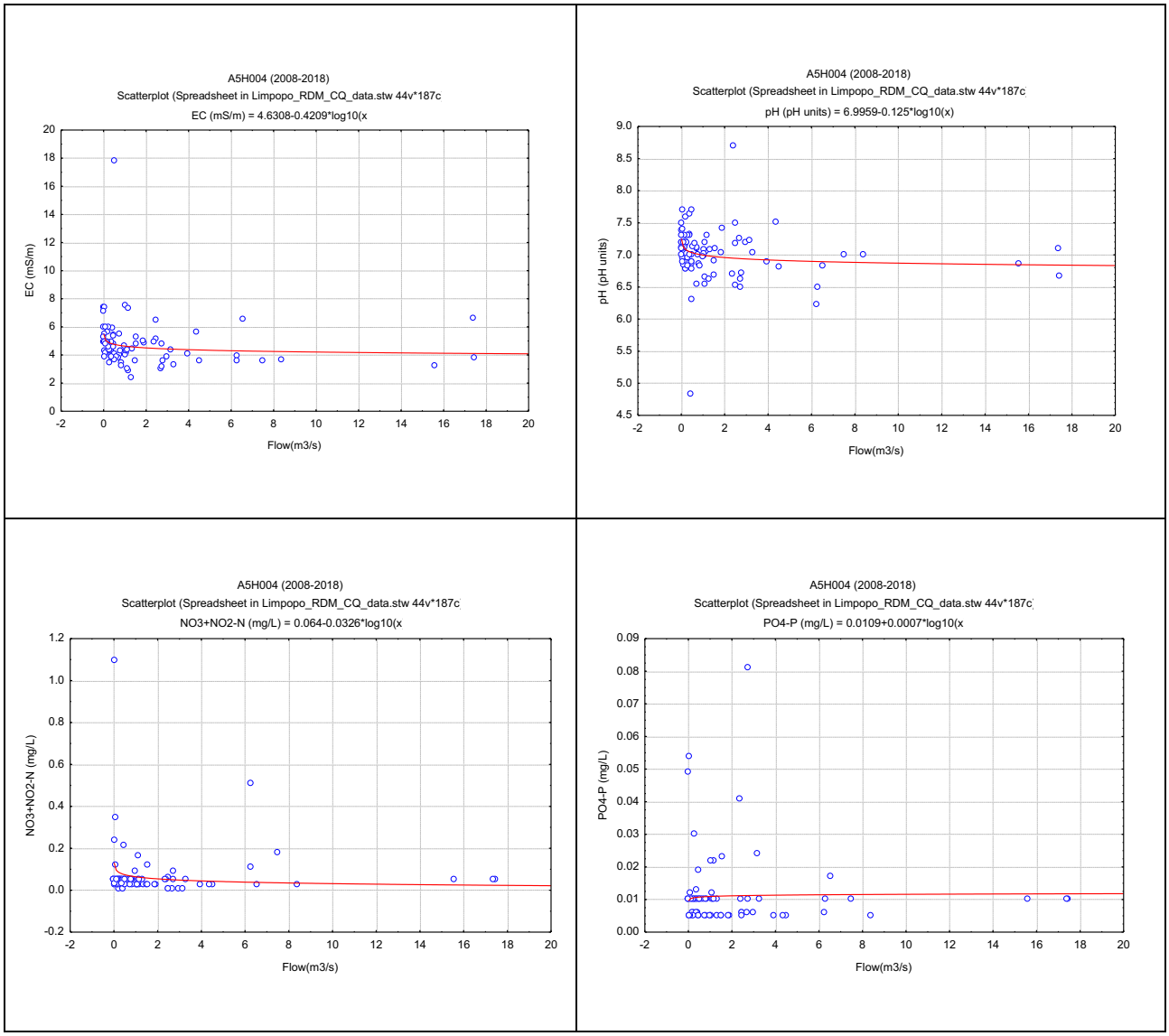


Figure 4.2: Relationships between flow and EC, pH, NO_2+NO_3-N, and PO_4-P at 1_Lephalala

4.2.3.2 2_Rietfontein

2_Rietfontein was fed from a spring with high salinity. There was a monitoring point where 48 samples have been collected between 1995 and 2017. The sampling point was called WMS A63_89777 ZQMTUG4 2228DA00520 Tugela Bad (N_GW) Spring/Eye. The summary statistics for selected constituents are presented in **Table 4.11**. The reference conditions were probably equal to the present state because the quality of the spring water would exhibit little change over time.

The WQ was in a **B/C** category (**Table 4.12**).

Table 4.11: Water quality summary statistics for 2_Rietfontein

ZQMTUG4	N	Mean	Median	Min	Max	25%tile	75%tile	5%tile	95%tile	Std.Dev.
Ca (mg/l)	19	129.69	125.66	109.22	170.23	120.69	133.20	114.46	156.22	14.94
Cl (mg/l)	20	424.84	419.59	378.03	526.52	403.16	439.43	378.33	468.17	33.51
EC (mS/m)	20	239.21	238.20	226.60	258.00	233.48	244.45	227.65	253.35	8.83
Mg (mg/l)	19	1.29	0.75	0.75	2.60	0.75	1.73	0.75	2.51	0.69
Na (mg/l)	17	380.31	378.00	272.00	443.49	369.00	400.40	323.37	431.74	39.61
NH_4-N (mg/l)	20	0.06	0.05	0.03	0.17	0.03	0.10	0.03	0.13	0.04
NO_3-NO_2-N (mg/l)	20	0.09	0.05	0.01	0.93	0.03	0.05	0.01	0.18	0.20
pH	20	7.43	7.50	6.21	7.85	7.30	7.65	6.87	7.80	0.37
PO_4-P (mg/l)	20	0.01	0.01	0.01	0.09	0.01	0.01	0.01	0.04	0.02
SO_4 (mg/l)	20	491.43	477.35	233.82	783.72	458.81	501.24	406.57	636.00	102.35

Table 4.12: PAI results for 2_Rietfontein

IUA	Kalk pan se loop	Water quality points	
River & Quat	Rietfontein (A63C)	RC	No WQ sampling point in IUA
EWR site	2_Rietfontein	PES	ZQMTUG Tugela Bad Spring/Eye (2008-2017) N = 20 for EC
Confidence assessment	Low – moderate		
Water quality constituents		PES value	Category (Rating)
Nutrients	PO_4-P (mg/l) median	0.01	1
	TIN (mg/l) median	0.1	1
Physical variables	pH May 2023	7.51	1
	T (°C) May 2023	22.38	1
	DO (mg/l) *May 2023*	8.81 mg/l / 110.3%	3
	Turbidity (NTU)	No data	2
	EC (mS/m) *May 2023*	253.35	4
Overall site classification (from PAI)		**B/C** (78.3%)	

Average monthly water temperatures (°C) at 2_Rietfontein are given in **Table 4.13**.

Table 4.13: Average monthly water temperatures at 2)_Rietfontein

Calendar month											
J	F	M	A	M	J	J	A	S	O	N	D
26.7	25.8	24.9	23.1	19.5	16.8	16.8	19.5	22.2	24.9	25.8	26.7

4.2.3.3 3_Olifantspruit

The closest DWS water quality sampling point was A6H012Q01 (Olifant Spruit at Olifantspoort) where 546 samples have been collected from 1972 to 2018. The data from 2008-2018 were used in the analysis and the summary statistics are presented in **Table 4.14**.

The WQ was in a **B** category **(Table 4.15**).

Table 4.14 Water quality summary statistics for 3_Olifantsfontein

A6H012Q01	N	Mean	Median	Min	Max	25%tile	75%tile	5%tile	95%tile	Std.Dev.
Ca (mg/L)	79	4.008	3.803	1.250	8.468	3.204	4.717	1.250	6.800	1.356
Cl (mg/L)	80	5.422	4.919	2.674	9.557	4.299	6.182	3.506	9.045	1.541
EC (mS/m)	82	7.297	6.775	4.010	12.230	6.200	8.370	5.510	9.900	1.504
Mg (mg/L)	79	1.674	1.714	0.750	4.000	0.750	2.300	0.750	2.866	0.845
NH4-N (mg/L)	80	0.043	0.050	0.025	0.166	0.025	0.050	0.025	0.098	0.026
NO3+NO2-N (mg/L)	79	0.074	0.050	0.005	0.513	0.025	0.087	0.005	0.212	0.079
Na (mg/L)	70	3.322	2.828	0.700	11.656	2.000	4.501	1.200	6.376	1.899
PO4-P (mg/L)	80	0.016	0.010	0.005	0.179	0.005	0.010	0.005	0.073	0.028
SO4 (mg/L)	80	1.877	1.500	0.375	9.585	1.500	2.050	0.600	3.559	1.369
pH (pH units)	82	7.577	7.651	5.400	7.924	7.532	7.717	7.252	7.817	0.312

Table 4.15: PAI results for 3_Olifantspruit

IUA	Upper Nyl/Sterk	Water quality points	
River & Quat	Olifantspruit (A61A)	RC	Default boundary tables for "A" category river
EWR site	3_Olifantspruit	PES	A6H012Q01 – (2008-2018) n = 82
Confidence assessment	Moderate to high		
Water quality constituents		PES value	Category (Rating
Nutrients	PO_4-P (mg/l) median	0.010	1
	TIN (mg/l) median	0.100	0
Physical variables	pH	7.3 – 7.8	0
	T (°C)	20.34	1
	DO (mg/l)	8.13 mg/l / 103%	1
	Turbidity (NTU)	No data	1
	EC (mS/m) 95th percentile	9.9	0
Response variables	SASS (ASPT) score	6.1	
Overall site classification (from PAI)		**B** (87.3%)	

The salinity at this site was low and there were weak increasing trends in EC and nutrients (**Figure 4.3**), probably the result of limited agricultural development upstream of the sampling site.

There were weak negative relationships between flow and EC, pH and PO_4-P and a weak positive relationship with NO_2+NO_3-N (**Figure 4.4**).

Average monthly water temperatures (°C) at 3_Olifantspruit are given in **Table 4.16**.

Table 4.16: Average monthly water temperatures at 3_Olifantspruit

Calendar month											
J	F	M	A	M	J	J	A	S	O	N	D
19.5	20.0	18.9	17.3	15.0	13.4	13.4	15.0	17.3	18.9	19.5	19.5

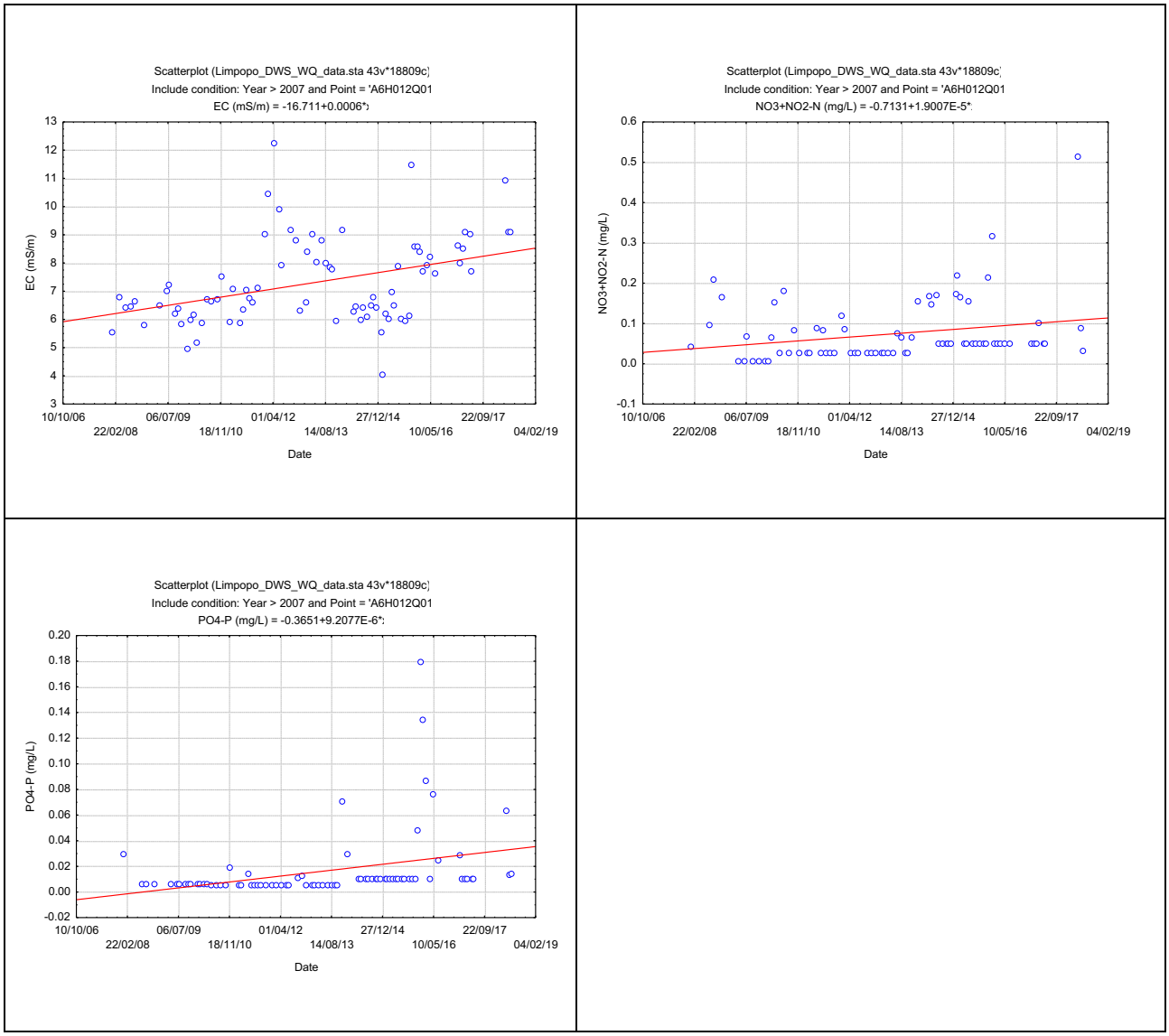


Figure 4.3: Time series plots of EC, NO2+NO3-N and PO4-P for 3_Olifantspruit

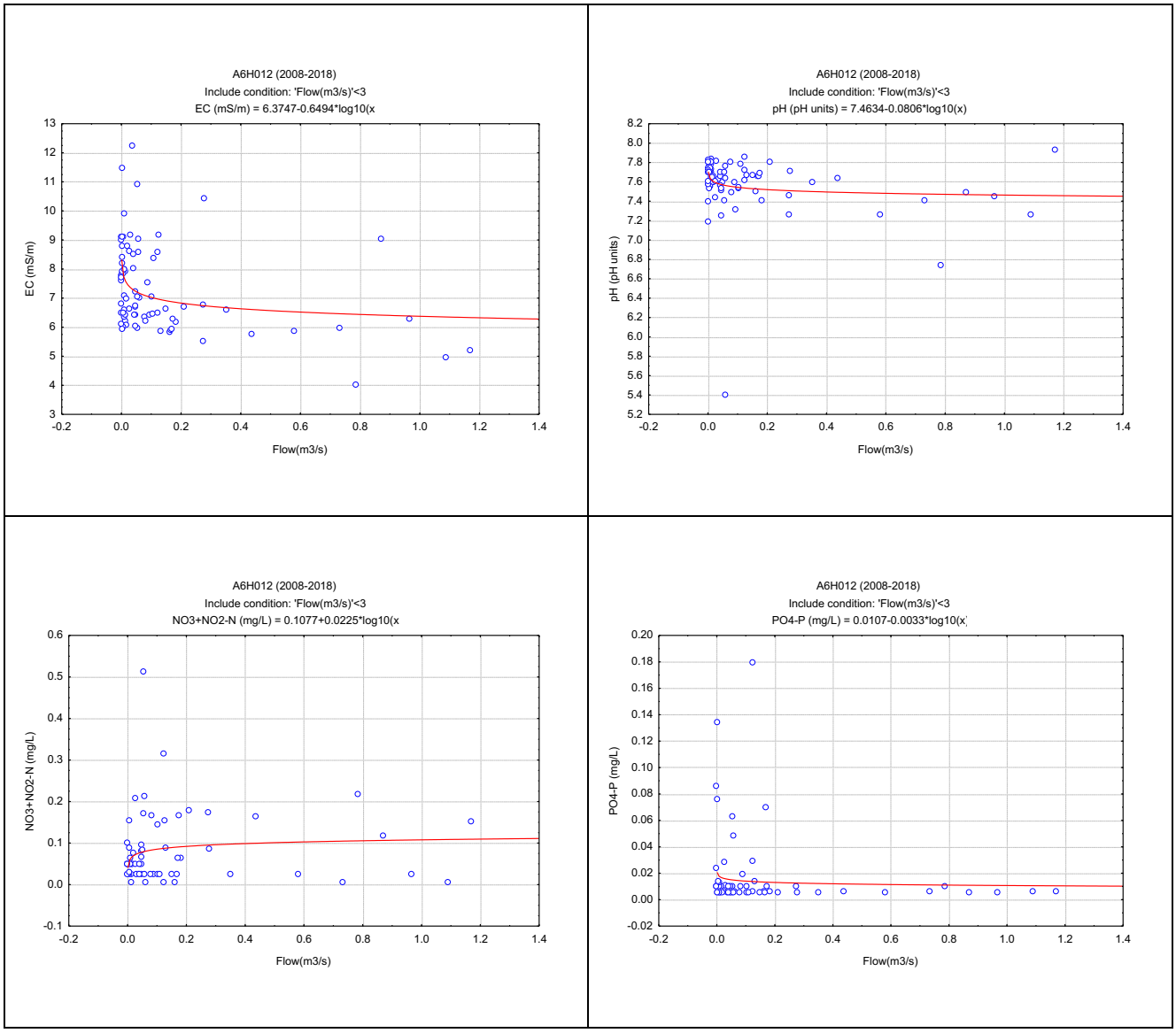


Figure 4.4: Relationships between flow and EC, NO2+NO3-N, PO4-P and pH at A6H012Q01

4.2.3.4 4_Mogalakwena1

There were no long-term water quality sampling points in the Mogalakwena River upstream of 4_Mogalakwena1 near Mokopane. There was a sampling point downstream called WMS A62_1000004273 - Mabuladihlare Haakoorndraai 758 LR Bridge downstream of George Masebe Hospital Oxidation Ponds, where 68 samples have been collected between 2005 and 2017. Water quality was probably affected by WWTW discharges from Mokopane, industrial effluents and industrial stormwater runoff, urban runoff and urban sprawl, and runoff and effluents from the Mogalakwena platinum mine. The water quality statistics for the site WMS 1000004273 are summarised in **Table 4.17.**

The WQ was in a **C** category (**Table 4.18**).

Table 4.17: Summary statistics for 4_Mogalakwena

A62_1000004273	N	Mean	Median	Min	Max	25%tile	75%tile	5%tile	95%tile	Std.Dev.
Ca (mg/L)	15	10.647	10.610	7.82	16.390	8.410	12.360	7.820	16.390	2.405
Cl (mg/L)	21	18.320	11.300	3.00	67.800	9.000	19.000	6.600	56.000	16.573
EC (mS/m)	21	22.417	15.220	9.33	113.200	12.200	19.600	10.100	54.800	23.055
Mg (mg/L)	18	4.213	3.585	0.50	11.750	3.200	5.070	0.500	11.750	2.311
NH_4-N (mg/L)	2	0.325	0.325	0.05	0.600	0.050	0.600	0.050	0.600	0.389
NO_3+NO_2-N (mg/L)	5	0.792	0.360	0.05	3.000	0.150	0.400	0.050	3.000	1.243
Na (mg/L)	19	11.376	10.290	0.28	28.210	8.650	14.380	0.280	28.210	5.603
PO_4-P (mg/L)	13	0.100	0.050	0.02	0.270	0.050	0.200	0.020	0.270	0.084
SO_4 (mg/L)	20	10.798	5.010	0.50	95.000	3.295	6.560	1.430	67.500	21.424
pH (pH units)	21	8.092	8.100	7.47	8.410	8.000	8.200	7.900	8.400	0.202

Table 4.18: PAI results for 4_Mogalakwena

IUA	Upper Nyl/Sterk	Water quality points	
River & Quat	Mogalakwena (A61G)	RC	No sampling point
EWR site	4_Mogalakwena	PES	WMS 1-4273 (2008-2017) N = 21 for EC
Confidence assessment	Low		
Water quality constituents		PES value	Category
Nutrients	PO_4-P (mg/l) median	0.05	3
	TIN (mg/l) median	0.7	2
Physical variables	pH 5th and 95th percentiles	7.9 – 8.4	1
	T (°C) May 2023 survey	21.36	0
	DO (mg/l)	No survey data	2
	Turbidity (NTU)	No survey data	3
	EC (mS/m) 95th percentile	54.8	2
Response variables	SASS (ASPT) score	6.1	
Overall site classification (from PAI)		**C** (68.8%)	

There was a slight increasing trend in Electrical Conductivity and a decreasing trend in nutrients (**Figure 4.5**). However, there were few data points and therefore low confidence in this trend.

There were no flow measurements at this site to examine the relationship between flow and water quality.

Average monthly temperatures (°C) at 4_Mogalakwena1 are given in **Table 4.19**.

Table 4.19: Average monthly temperatures at 4_Mogalakwena1

Calendar month											
J	F	M	A	M	J	J	A	S	O	N	D
20.6	20.6	20.0	18.4	16.2	14.5	14.5	16.2	18.4	19.5	20.0	20.6

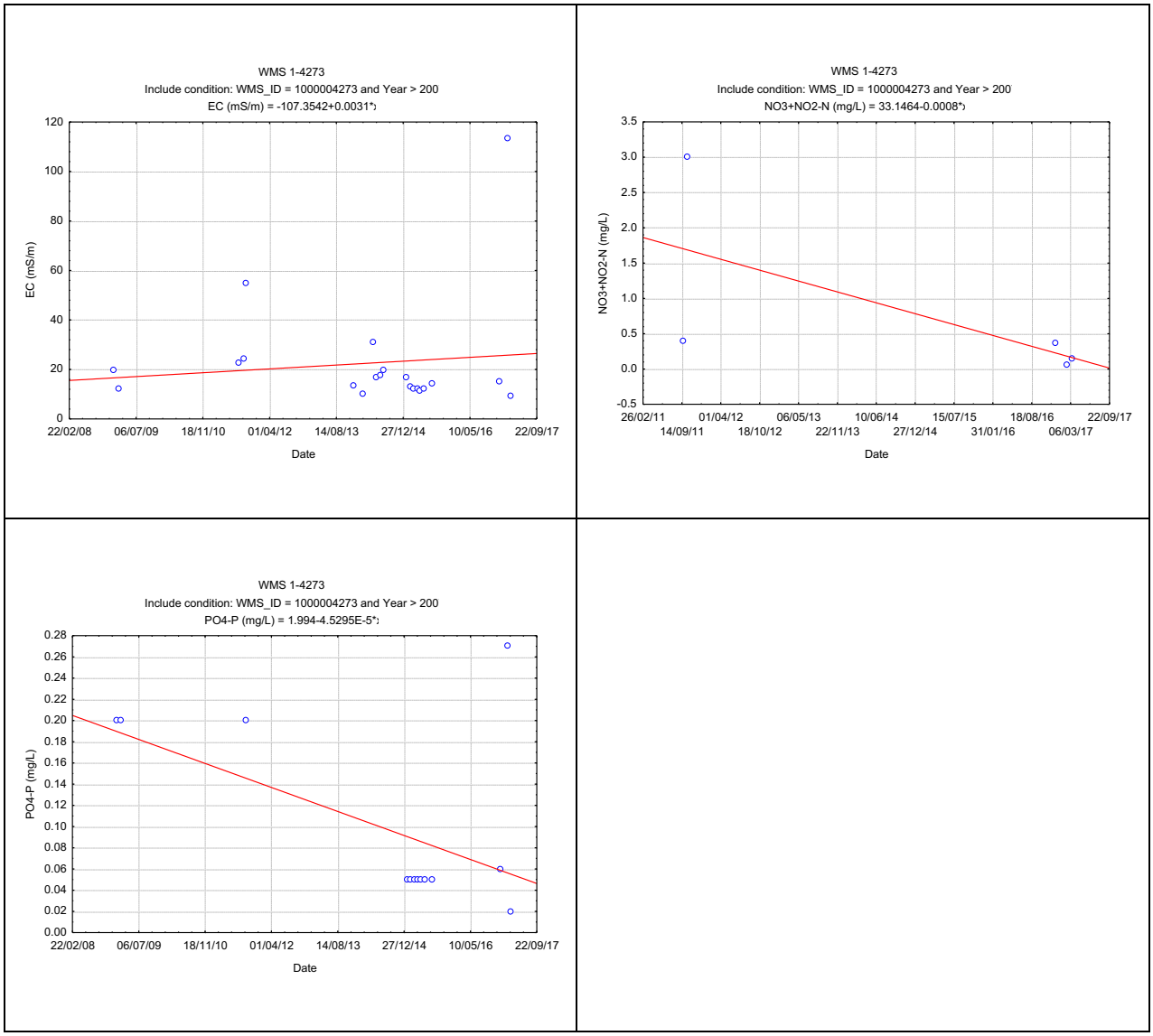


Figure 4.5: Time series plots of EC, NO_2+NO_3-N and PO_4-P recorded at WMS 1000004273 (2008-2017).

4.2.3.5 5_Mogalakwena2

The closest DWS water quality sampling point was A6R002Q01 (Glen Alpine Dam) where 710 samples have been collected from 1975 to 2018. Data from 2008 and 2018 were used for the summary statistics Table 4.20.

The WQ was in a **B/C** category (**Table 4.21**).

Table 4.20: Water quality summary statistics for 5_Mogalakwena

A6R002Q01	N	Mean	Median	Min	Max	25%tile	75%tile	5%tile	95%tile	Std.Dev.
Ca (mg/L)	123	20.14	16.136	4.993	66.800	13.580	22.055	9.645	48.900	12.152
Cl (mg/L)	127	38.31	26.795	8.478	270.70	18.998	43.189	13.70	74.500	37.003
EC (mS/m)	130	32.08	24.982	11.49	186.00	19.900	38.900	14.97	75.700	24.692
Mg (mg/L)	123	8.964	6.576	0.750	41.900	4.845	10.722	2.809	23.000	7.464
NH4-N (mg/L)	127	0.076	0.050	0.025	1.031	0.025	0.050	0.025	0.210	0.130
NO3+NO2-N (mg/L)	128	0.118	0.050	0.005	1.230	0.040	0.118	0.025	0.448	0.182
Na (mg/L)	99	25.74	18.783	0.800	182.10	13.523	24.841	8.913	92.600	27.488
PO4-P (mg/L)	127	0.042	0.010	0.005	0.541	0.006	0.021	0.005	0.319	0.099
SO4 (mg/L)	128	7.838	6.048	0.817	44.631	4.456	9.830	2.900	16.604	6.076
pH (pH units)	131	8.093	8.144	6.932	8.600	7.917	8.300	7.524	8.500	0.302

Table 4.21: PAI results for 5_Mogalakwena

IUA	Mogalakwena	Water quality points	
River & Quat	Mogalakwena (A62J)	RC	
EWR site	5_Mogalakwena	PES	A6R002Q01 (2008-2018) n= 130
Confidence assessment	Moderate to high		
Water quality constituents		PES value (or summary statistic)	Category (Rating) / Comment
Nutrients	PO_4-P (mg/l) median	0.010	1
	TIN (mg/l) median	0.100	0
Physical variables	pH 5th and 95th percentiles	7.5 – 8.5	1
	T (°C) May 2023	21.92	3
	DO (mg/l) *May 2023*	8.15 mg/l 102%	2
	Turbidity (NTU)	No field data	1
	EC (mS/m) 95th percentile	75.7	2
Response variables	SASS (ASPT) score	5.3	
Overall site classification (from PAI)		**B/C** (80.6%)	

Electrical Conductivity increases with time and shows a strong seasonal cycle of increasing in the dry season and diluting in the wet season. There are no trends in nutrients (**Figure 4.6**).

There is a weak negative relationship between flow, EC, pH and PO_4-P, due to dilution, and a weak positive with NO_2-NO_3-N (**Figure 4.6**). The inverse relationship indicates the impacts of dilution during the wet season.

Average monthly temperatures (°C) at 5_Mogalakwena2 are given in **Table 4.22**.

Table 4.22: Average monthly temperatures at 5_Mogalakwena2

Calendar month											
J	F	M	A	M	J	J	A	S	O	N	D
20.6	20.6	20.0	18.4	16.7	15.0	15.0	16.7	18.4	20.0	20.0	20.6

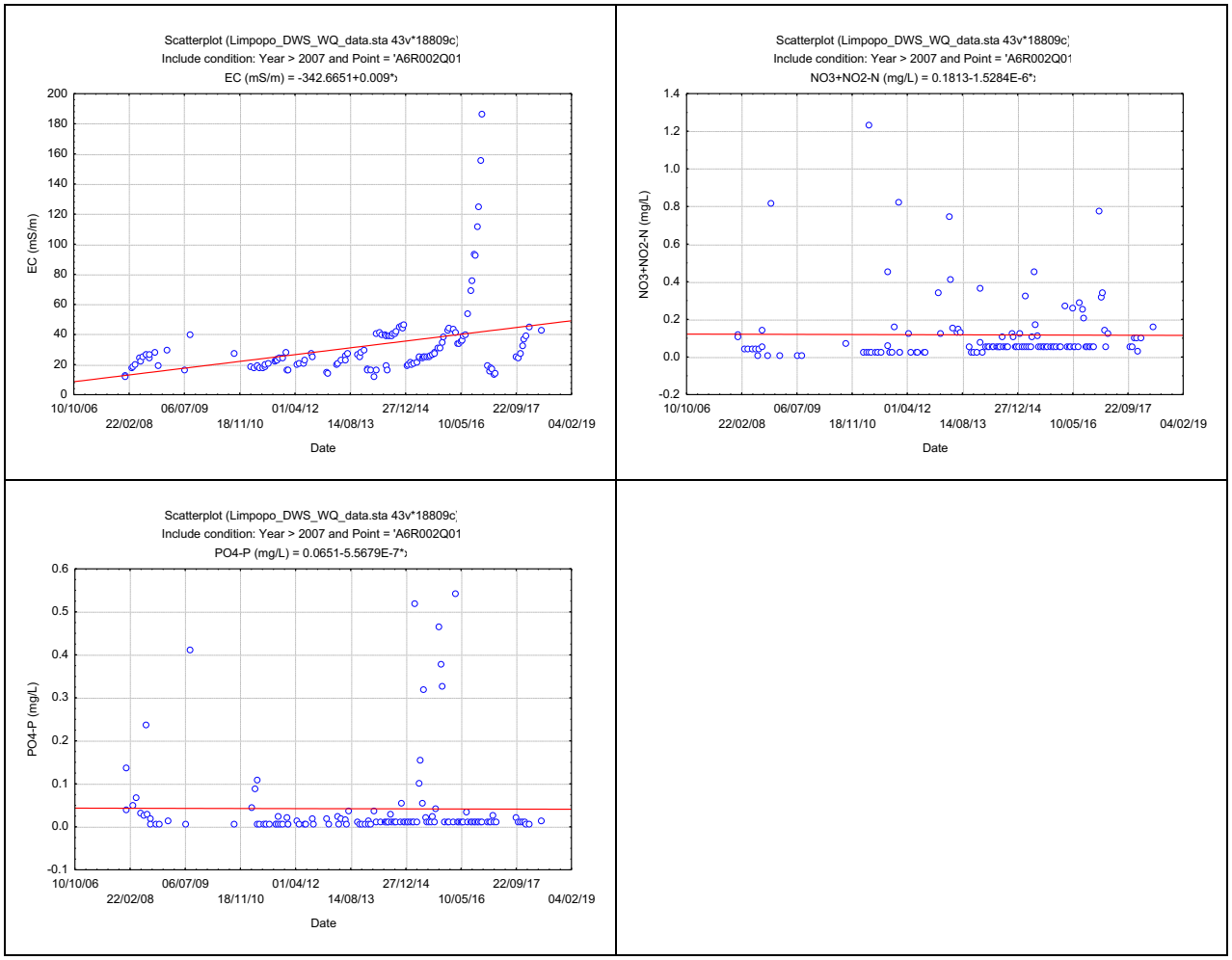


Figure 4.6: Time series plots of EC, NO_2+NO_3-N and PO_4-P for 5_Mogalakwena

4.2.3.6 6_Kolope

There was no sampling point in this catchment, so the water quality was assessed qualitatively based on generalised relationships.

The WQ was estimated to be in a **B/C** category (**Table 4.24**). Water quality in the Kolope River would be characteristic of a non-perennial stream with high fluctuations in quality. Salinity would fluctuate widely as accumulated salts are washed off the catchment, pools start forming when flows stop, and salinity increase as water evaporate from the pools leaving behind the salts. These are natural processes, but it is agrivated by degradation of the catchment. The degraded state of the Kolope catchment (large areas of bare soil and widespread overgrazing), presence of the shallow Leeu Pan, widespread erosion along the riverbanks, and high sediment loads during floods all contribute to the estimation that the rivers is in a **B/C** category (modified water quality state).

Average monthly temperatures (°C) at 6_Kolope are given in **Table 4.23**.

Table 4.23: Average monthly temperatures at 6_Kolope

Calendar month											
J	F	M	A	M	J	J	A	S	O	N	D
21.7	21.1	20.6	18.9	17.3	15.6	15.0	16.7	18.9	20.0	21.1	21.1

Table 4.24: PAI results for 6_Kolope

IUA	Kolope		Water quality points	
River & Quat	Kolope (A63E)		RC	No data
EWR site	6_Kolope		PES	No data
Confidence assessment	Low			
Water quality constituents			PES value	Category
Nutrients	PO_4-P (mg/l)			1
	TIN (mg/l)			1
Physical variables	pH			1
	T (°C)			2
	DO (mg/l)			2
	Turbidity (NTU)			2
	EC (mS/m)			3
Overall site classification (from PAI)			**B/C** (79.4%)	

4.2.3.7 7_Sand

There were no water quality sampling points near 7_Sand so the water quality was assessed qualitatively based on generalised relationships and observations by DWS staff. DWS established a monitoring point in 2022 downstream of the confluence of the Bloed and Sand rivers that can in future be used to assess the water quality status of the Sand River upstream of the EWR site 7_Sand. This point is referred to as WMS 1000265560 – Sand River at Soetdorings downstream of Polokwane WWTW Ponds next to ZZ2 Farm. Data for 3 sampling events in 2022 are available on WMS but this is outside of the data period used for all the other present state assessments in this report.

The WQ was in a **D** category (**Table 4.25**).

Table 4.25: PAI results for 7_Sand

IUA	Upper Sand		Water quality points	
River & Quat	Sand (A71C)		RC	No data
EWR site	R-i-20		PES	WMS 1000265560 (No data for assessment period)
Confidence assessment				
Water quality constituents			PES value (or summary statistic)	Category (Rating) / Comment
Nutrients	PO_4-P (mg/l)			4
	TIN (mg/l)			2
Physical variables	pH			2
	T (°C)			2
	DO (mg/l)			3
	Turbidity (NTU)			4
	EC (mS/m)			4
Overall site classification (from PAI)			**D** (53.5%)	

Average monthly water temperatures (°C) at 7_Sand are given in **Table 4.26.**

Table 4.26: Average monthly water temperatures at 7_Sand

Calendar month											
J	F	M	A	M	J	J	A	S	O	N	D
20.0	20.0	18.9	17.8	16.2	14.5	14.5	15.6	17.8	18.9	19.5	20.0

4.2.3.8 8_Nzhelele

The DWS water quality sampling point closest to 8_Nzhelele was A8R001Q01 - Nzhelele Dam on Nzhelele River: near Dam Wall, 60km upstream. The water quality data are summarised in **Table 4.27**.

Limited samples have been collected downstream of Ṅwaneḍi and Luphephe dams on the Ṅwaneḍi River and since these two rivers are in the same basin with similar land use the data were used for both rivers. In the absence of monitoring data downstream of Nzhelele Dam, the PAI assessment was done with data collected in the lower Ṅwaneḍi River.

Table 4.27: Water quality summary statistics for 8_Nzhelele

194545&194544	N	Mean	Median	Min	Max	25%tile	75%tile	5%tile	95%tile	StdDev
Cl (mg/l)	8	44.13	38.21	9.06	121.68	19.30	55.11	9.40	100.09	36.43
EC (mS/m)	8	44.56	39.95	24.00	74.50	33.68	51.15	24.11	74.05	19.47
Mg (mg/l)	8	12.56	13.45	3.80	19.82	8.37	16.60	5.31	18.79	5.38
Na (mg/l)	8	45.27	33.33	19.34	101.78	25.09	56.32	20.19	93.10	29.71
NO3+NO2-N (mg/l)	2	0.43	0.43	0.35	0.50	0.39	0.46	0.36	0.49	0.11
pH (pH units)	8	7.66	7.53	7.20	8.37	7.45	7.77	7.27	8.29	0.40
PO4-P (mg/l)	8	0.10	0.06	0.02	0.31	0.02	0.13	0.02	0.28	0.11
SO4 (mg/l)	8	13.16	9.58	0.50	39.35	4.19	19.66	1.04	32.47	12.84
TAL (mg/l)	8	35.00	6.00	2.00	190.00	3.50	23.50	2.00	143.80	65.36

The WQ was in a **C** category (**Table 4.28**).

Table 4.28: PAI results for 8_Nzhelele

IUA	Nzhelele/Ṅwaneḍi	Water quality points	
River & Quat	Nzhelele (A80G)	RC	A8R001Q01 (2008–2018) n = 91 for EC
EWR site	8_Nzhelele	PES	WMS 194545, 194544 & 190607 (2008-2018) n=16
Confidence assessment	Moderate		
Water quality constituents		PES value (or summary statistic)	Category (Rating) / Comment
Nutrients	PO_4-P (mg/l) median	0.06	3
	TIN (mg/l) median	0.43	1
Physical variables	pH	7.3 – 8.3	1
	T (°C) May 2023	22.73	2
	DO (mg/l) *May 2023*	9.59 mg/l / 117.1%	2
	Turbidity (NTU)	No data	2
	EC (mS/m)	74.05	2
Response variables	SASS (ASPT) score	6.0	
Overall site classification (from PAI)		**C** (71.2%)	

There are weak increasing trends in Electrical Conductivity and nutrients (**Figure 4.7**) and a strong seasonal signature of dilution in the wet season.

There are no relationships between flow and EC, pH or PO_4-P but there is a weak relationship between flow and NO_3+NO_2 (**Figure 4.8**).

Average monthly water temperatures (°C) at 8_Nzhelele are given in **Table 4.29**.

Table 4.29: Average monthly water temperatures at 8_Nzhelele

Calendar month											
J	F	M	A	M	J	J	A	S	O	N	D
21.7	21.1	21.1	20.0	17.8	16.7	16.2	17.8	18.9	20.6	21.1	21.7

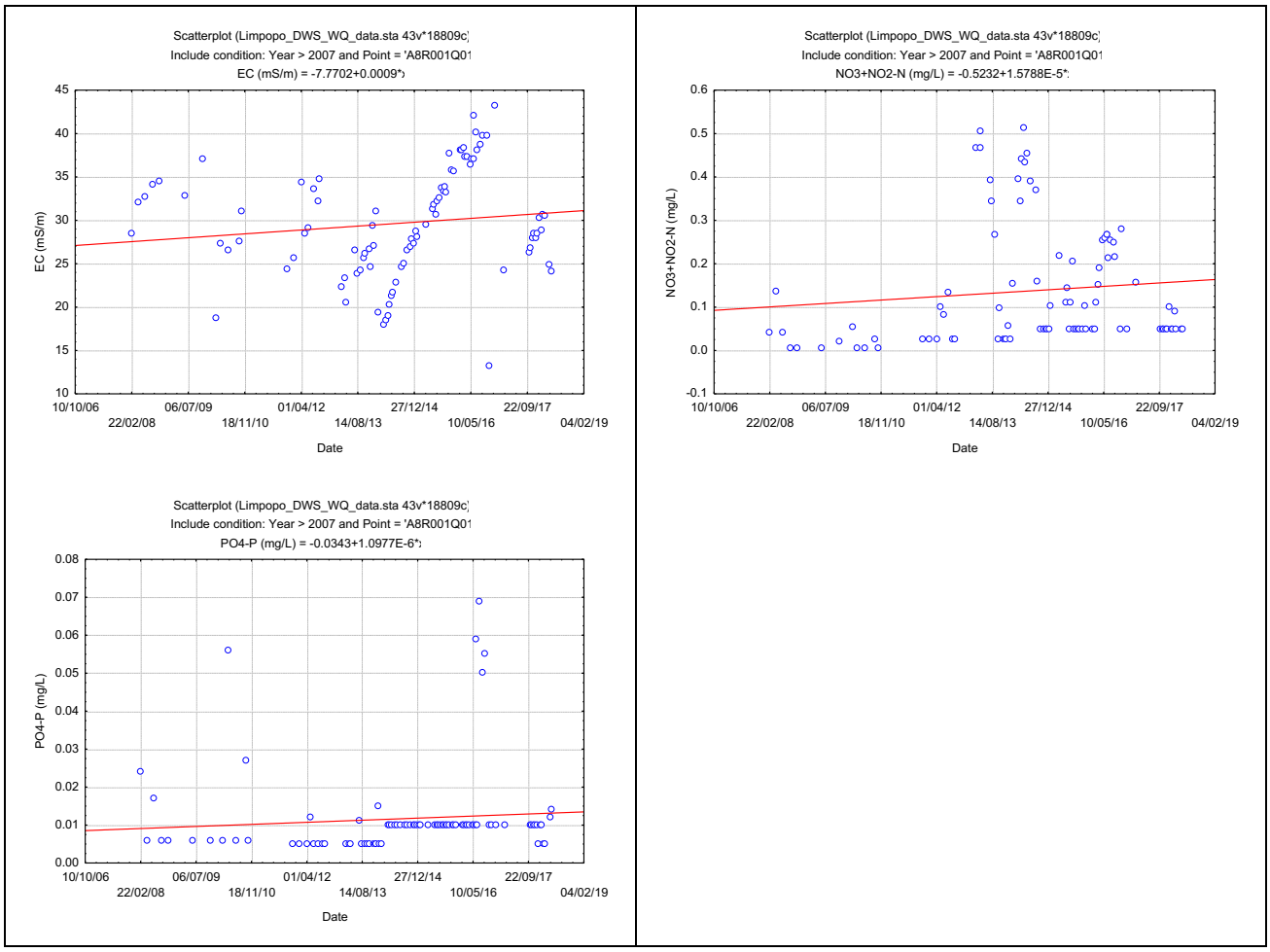


Figure 4.7: Time series plots of EC, NO2+NO3-N and PO4-P at 8_Nzhelele

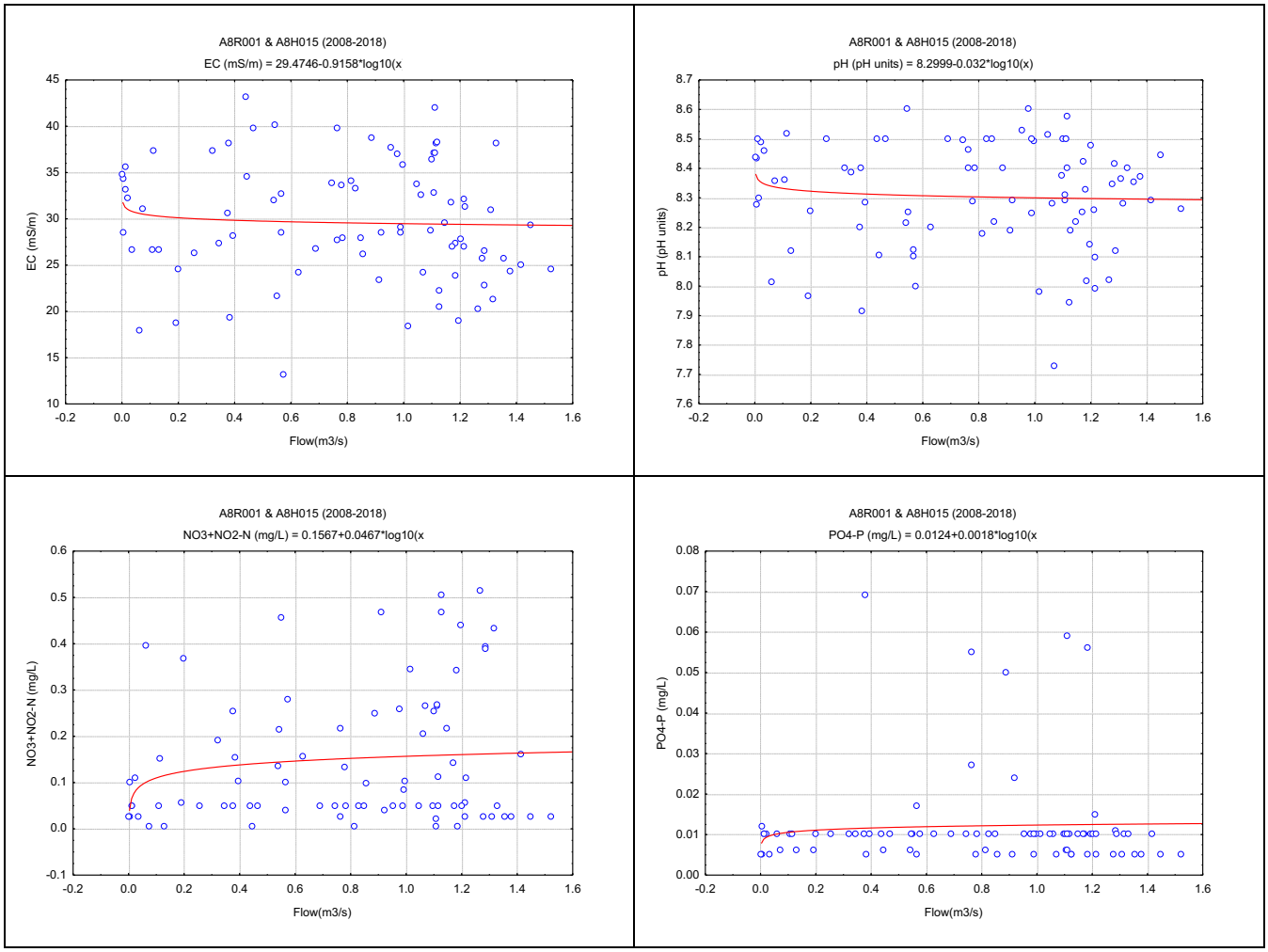


Figure 4.8: Relationships between flow, EC, NO2+NO3-N, PO4-P and pH at 8_Nzhelele

4.2.3.9 9_Ṅwaneḍi

The closest DWS water quality sampling point was A8R002Q01 (Luphephe Dam) where 510 samples have been collected from 1968 to 2018. Downstream of Luphephe Dam:

- 12 samples were collected at WMS 194545 (Folovhoḍwe) from August 2016 to March 2017
- 5 samples were collected at WMS 194544 (Agriven Depot) from January to March 2017
- 16 samples were collected at WMS 190607 (Malala Drift bridge) between 2011 and 2017.

- Data from 2008 to 2018 were used for the summary statistics (**Table 4.30**).

The WQ was in a **C** category (**Table 4.31**).

The salinity in Luphephe Dam was low and there were increasing trends for Electrical Conductivity and nitrogen but not for PO_4-P (**Figure 4.9**).

Downstream of Luphephe Dam there was a decreasing trend for Electrical Conductivity and increasing trends for nitrogen and PO_4-P (**Figure 4.10**).
There were negative relationships between flow, EC, pH and NO_2+NO_3-N and a weak positive relationship with PO_4-P (**Figure 4.11**).

There were no observed hydrological records downstream of Luphephe Dam for the flow-water quality relationships of WMS 194545, 194544 & 190607.

Table 4.30: Water quality summary statistics for 9_Ṅwaneḍi (A8R002Q01)

A8R002Q01	N	Mean	Median	Min	Max	25%tile	75%tile	5%tile	95%tile	Std.Dev.
Ca (mg/L)	84	5.549	4.799	1.798	21.400	3.492	7.020	2.781	9.800	2.726
Cl (mg/L)	84	19.145	18.787	11.261	28.600	15.083	24.050	11.822	26.800	5.119
EC (mS/m)	87	12.643	11.570	6.530	22.700	9.570	16.710	8.130	18.600	3.657
Mg (mg/L)	82	3.809	3.339	0.750	9.100	2.572	5.142	0.750	7.300	1.868
NH4-N (mg/L)	86	0.082	0.050	0.025	0.496	0.050	0.050	0.025	0.220	0.090
NO3+NO2-N (mg/L)	85	0.342	0.317	0.025	1.210	0.103	0.545	0.030	0.830	0.272
Na (mg/L)	65	10.642	11.377	1.395	19.500	7.183	14.000	3.000	16.200	4.202
PO4-P (mg/L)	86	0.039	0.010	0.000	0.475	0.010	0.012	0.005	0.232	0.089
SO4 (mg/L)	84	2.595	1.500	0.375	23.286	1.500	3.550	0.600	5.438	2.879
pH (pH units)	88	7.644	7.658	6.436	8.256	7.488	7.800	7.179	8.000	0.275

Table 4.31: PAI results for 9_Ṅwaneḍi

IUA	Nzhelele/Ṅwaneḍi	Water quality points	
River & Quat	Ṅwaneḍi (A80J)	RC	
EWR site	9_Ṅwaneḍi	PES	WMS 194545 & 194544 (2008-2018) n=8
Confidence assessment	Moderate		
Water quality constituents		PES value (or summary statistic)	Category (Rating) / Comment
Nutrients	PO_4-P (mg/l) median	0.06	3
	TIN (mg/l) median	0.43	1
Physical variables	pH 5th & 95th percentile	7.2 – 8.3	1
	T (°C) May 2023	21.82	2
	DO (mg/l)	7.78 mg/l / 93.4%	2
	Turbidity (NTU)	No data	2
	EC (mS/m) 95th percentile	74.5	2
Response variables	SASS (ASPT) score	6.1	
Overall site classification (from PAI)		**C** (71.2%)	

Average monthly temperatures (°C) at 8_Nzhelele are given in **Table 4.32**.

Table 4.32: Average monthly temperatures at 9_Ṅwaneḍi

Calendar month											
J	F	M	A	M	J	J	A	S	O	N	D
21.7	21.1	20.6	20.0	18.4	16.7	16.7	17.8	18.9	20.6	21.1	21.7

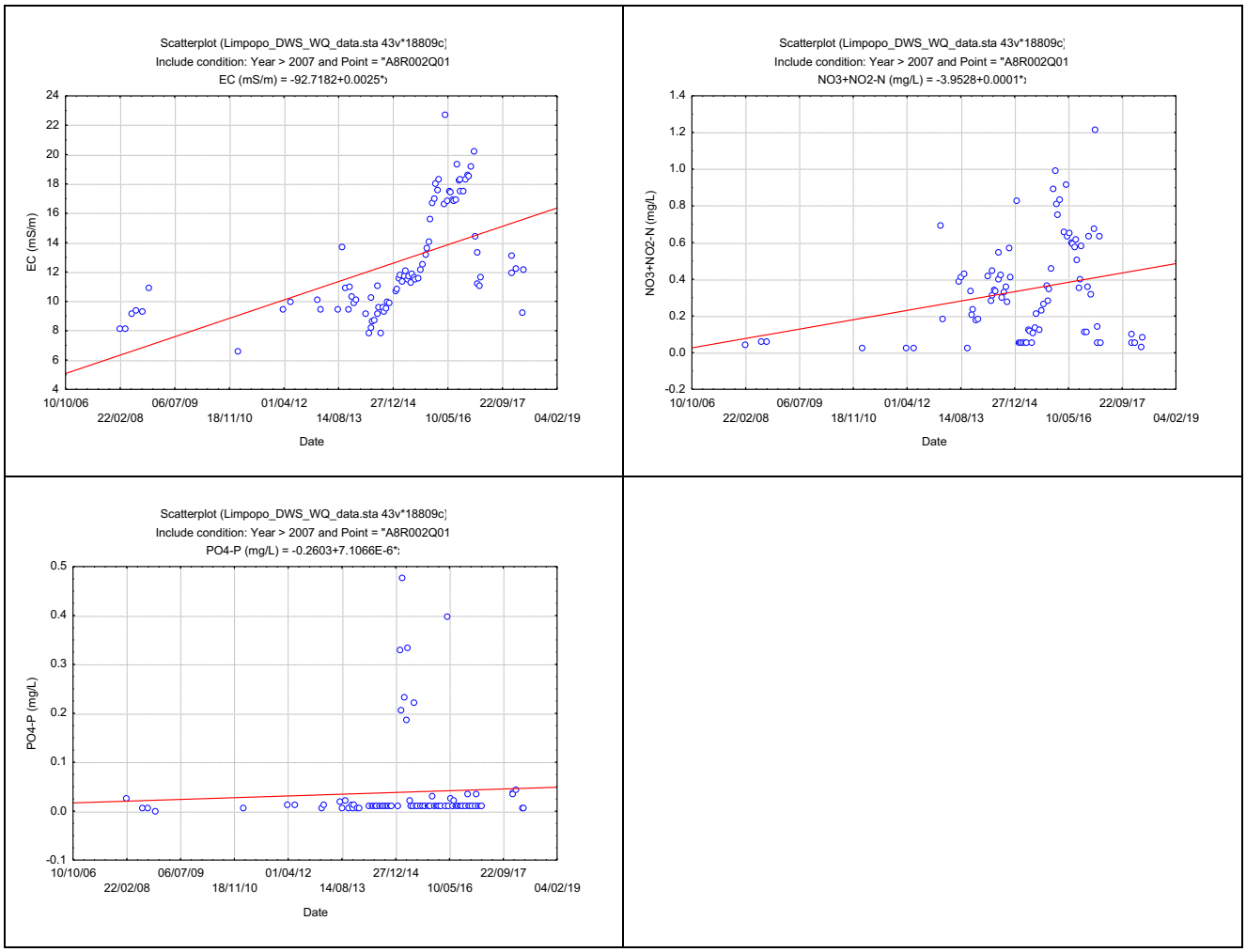


Figure 4.9: Time series plots of EC, NO2+NO3-N and PO4-P for A8R002Q01

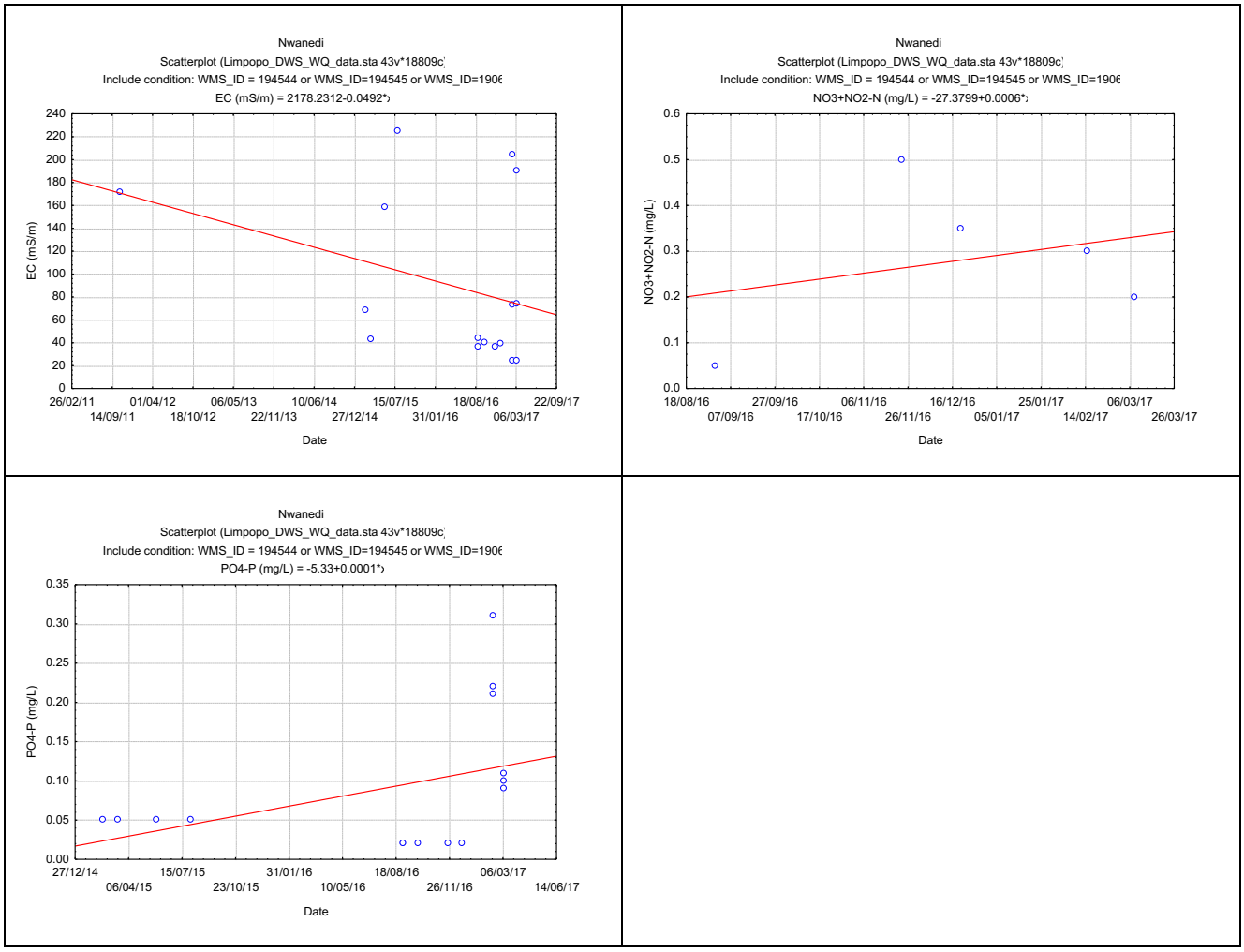


Figure 4.10: Time series plots of EC, NO2+NO3-N and PO4-P for WMS 194545, 194544 & 190607

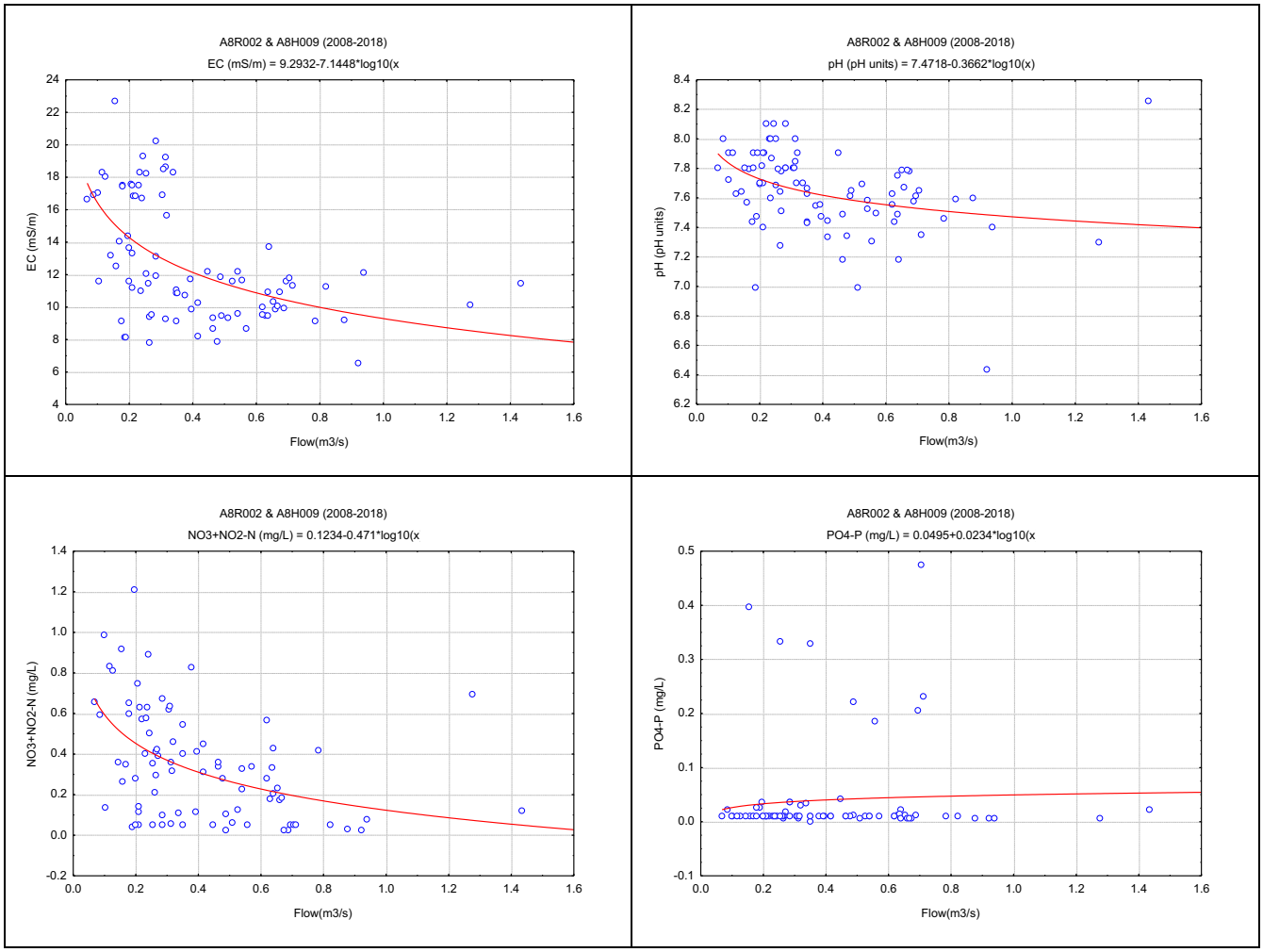


Figure 4.11: Relationships between flow and EC, NO2+NO3-N, PO4-P and pH at A8R002Q01 and A8H009

4.2.3.10 10_Latonyanda

The closest DWS water quality sampling point was A9H027 (Levubu Settlements) where 98 samples have been collected from 2007 to 2018. Data from 2008 to 2018 were used for the summary statistics (**Table 4.33)**.

The WQ was in a **A/B** category (**Table 4.34**).

Table 4.33: Summary water quality statistics for 10_Latonyanda

A9H027	N	Mean	Median	Min	Max	25%tile	75%tile	5%tile	95%tile	Std.Dev.
Ca (mg/L)	89	5.594	5.400	2.717	9.500	4.568	6.400	3.427	8.125	1.428
Cl (mg/L)	88	5.450	5.277	2.000	10.475	4.630	6.029	3.952	7.500	1.286
EC (mS/m)	91	9.131	9.070	4.340	12.980	8.350	10.040	7.160	11.320	1.294
Mg (mg/L)	90	3.277	3.324	0.750	5.926	2.828	3.828	1.738	4.800	0.985
NH4-N (mg/L)	91	0.047	0.050	0.025	0.193	0.025	0.050	0.025	0.143	0.033
NO3+NO2-N (mg/L)	91	0.233	0.242	0.005	0.654	0.146	0.302	0.025	0.430	0.127
Na (mg/L)	78	4.126	4.300	0.440	9.156	2.910	5.101	1.820	6.000	1.495
PO4-P (mg/L)	90	0.014	0.010	0.005	0.209	0.006	0.010	0.005	0.039	0.025
SO4 (mg/L)	88	1.537	1.500	0.375	3.000	0.600	1.550	0.600	3.000	0.878
pH (pH units)	93	7.780	7.845	6.777	8.119	7.699	7.907	7.369	8.022	0.223

Table 4.34: PAI results for 10_Latonyanda

IUA	Upper Luvuvhu/Mutale	Water quality points	
River & Quat	Latonyanda (A91D)	RC	
EWR site	10_Latonyanda	PES	A9H027 (2008-2018) n= 91 for EC
Confidence assessment	Moderate - high		
Water quality constituents		PES value	Category
Nutrients	PO_4-P (mg/l) median	0.010	1
	TIN (mg/l) median	0.292	1
Physical variables	pH 5th & 95th percentiles	7.4 – 8.0	0
	T (°C) May 2023	18.55	1
	DO (mg/l) *May 2023*	9.31 mg/l / 107.8%	0
	Turbidity (NTU)	No data	1
	EC (mS/m) 95th percentiles	11.32	0
Response variables	SASS (ASPT) score	7.1	
Overall site classification (from PAI)		**A/B** (91.8)	

The salinity at 10_Latonyanda is low and there were weak positive trends for Electrical Conductivity and nutrients (**Figure 4.12**).

There were negative relationships between flow, Electrical Conductivity, pH and PO4-P (**Figure 4.13**) and a positive relationship with NO_2+NO_3-N, due to leaching during wet periods.

Average monthly water temperatures (°C) at 10_Latonyanda are given in **Table 4.35**.

Table 4.35: Average monthly water temperatures at 10_Latonyanda

Calendar month											
J	F	M	A	M	J	J	A	S	O	N	D
20.0	20.0	19.5	18.4	17.3	15.6	15.6	16.7	18.4	18.9	20.0	20.0

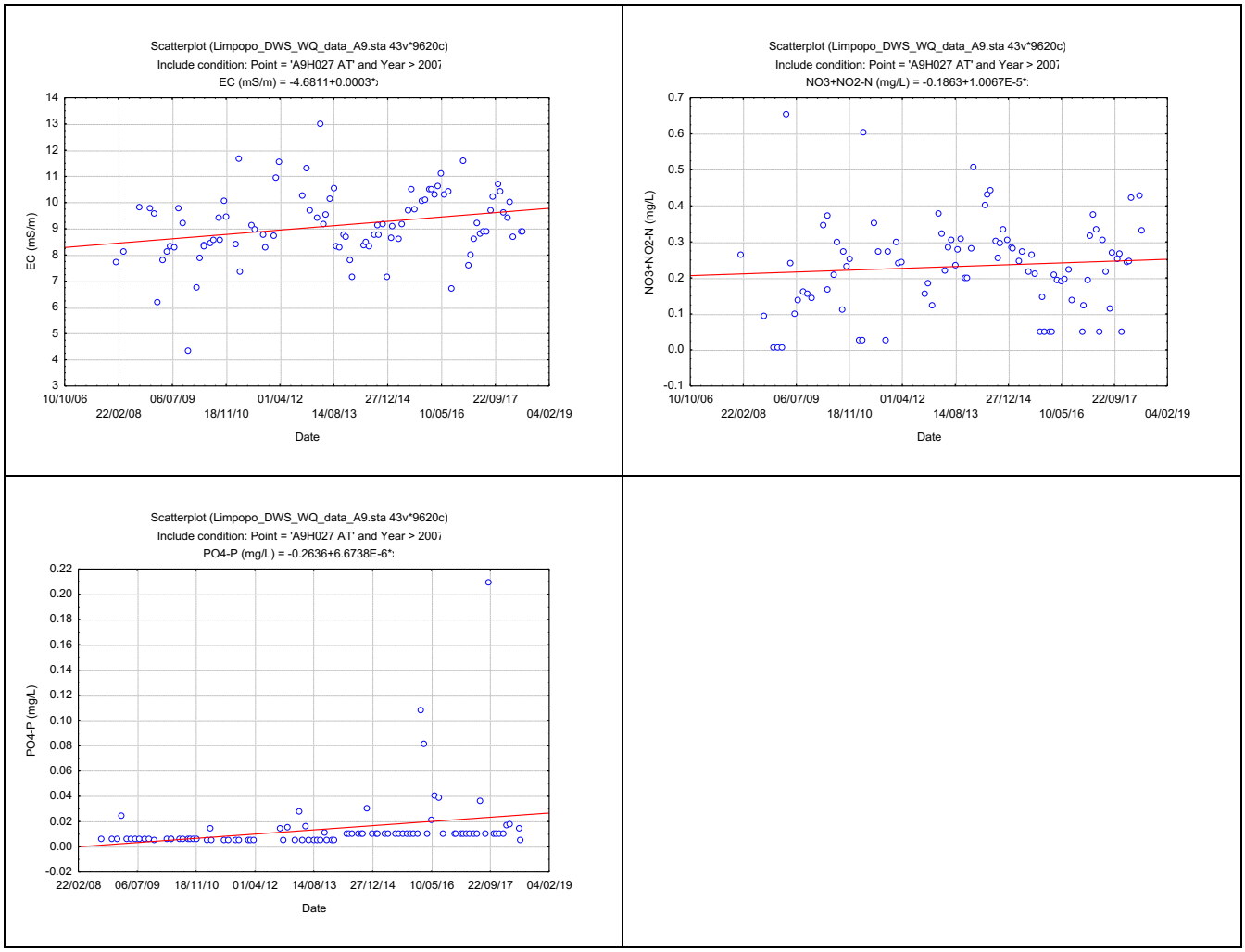


Figure 4.12: Time series plots of EC, NO2+NO3-N and PO4-P for 10_Latonyanda

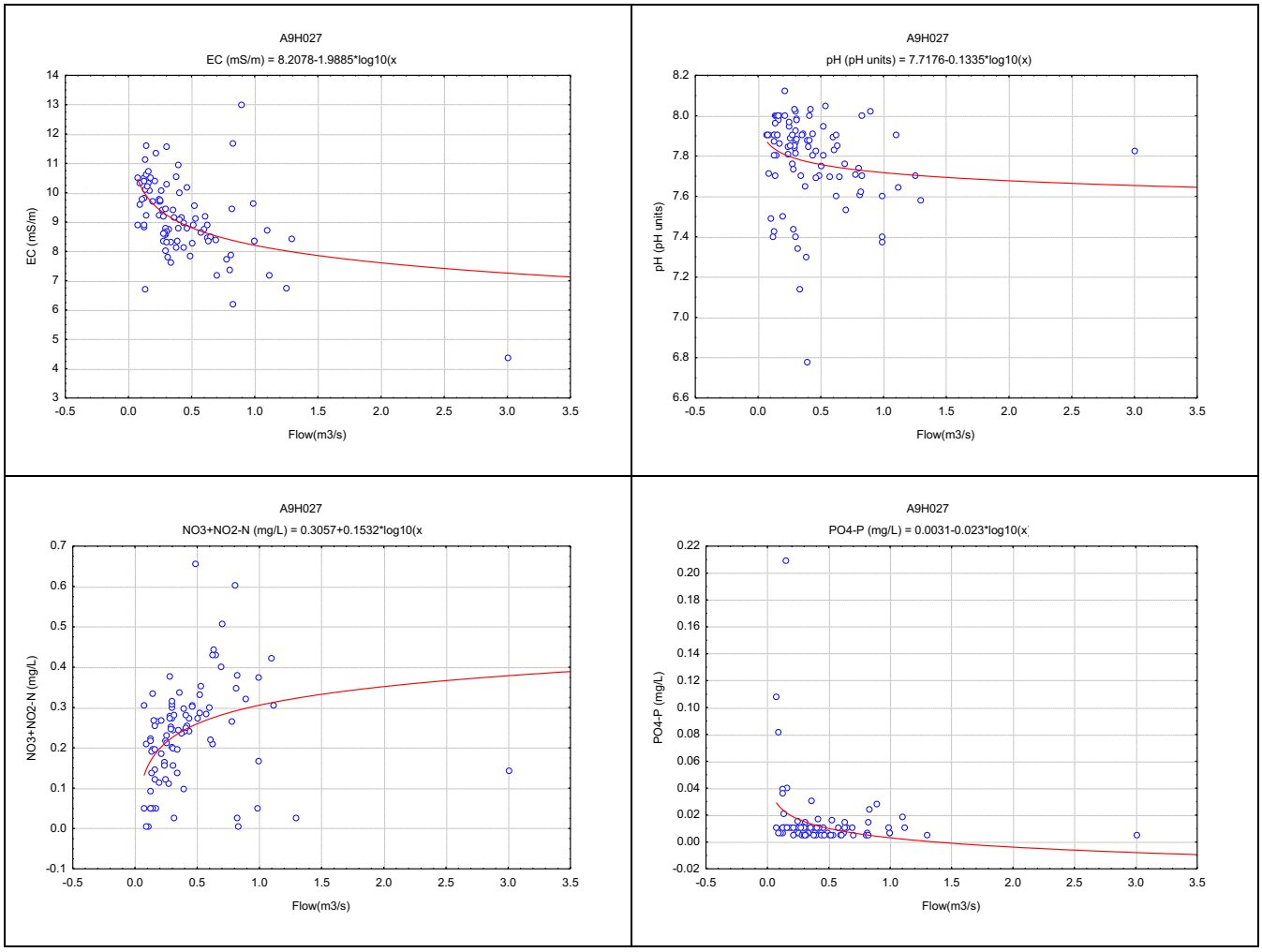


Figure 4.13: Relationship between flow, EC, pH, NO2+NO3-N, PO4-P for 10_Latonyanda

4.2.3.11 11_Mutshindudi

The closest DWS water quality sampling point was A9H025Q01 (Mutshindudi River at Vredenburg/Tshidzini) where 21 samples have been collected from 1997 and 2017. Data from 2008 and 2018 were used for the summary statistics (**Table 4.36**).

The data record at A9H025Q01 (Mutshindudi at Vredenburg/Tshidzini) runs from 1997 - 2017. However, from 1997-1999, nine samples were collected, then there is a gap of eight years when no sampling took place, and from 2007-2017, 12 samples were collected (only 1 in 2007). There is also a difference in WQ between the two data periods. EC concentrations were generally lower in the 1997-1999 period than 2008-2017. PO4-P concentrations were higher in the 1997-1999 period. NO3+NO2-N concentrations were only slightly lower in the 1997-1999 period. The data from the period 2008 - 2017 data set is the best reflection of the present WQ state in the river than using the whole data set (1997 - 2017).

The WQ is in a **B/C** category (**Table 4.37**).

Table 4.36: Water quality summary statistics for 11_Mutshindudi

A9H025Q01	N	Mean	Median	Min	Max	25%tile	75%tile	5%tile	95%tile	Std.Dev.
Ca (mg/L)	11	7.394	7.647	3.487	10.230	5.435	9.443	3.487	10.230	2.123
Cl (mg/L)	11	8.631	8.372	6.184	11.710	7.400	9.720	6.184	11.710	1.613
EC (mS/m)	10	11.189	11.790	6.860	15.500	8.540	12.250	6.860	15.500	2.608
Mg (mg/L)	11	4.677	4.911	2.462	6.430	2.983	5.815	2.462	6.430	1.341
NH4-N (mg/L)	11	0.032	0.025	0.025	0.072	0.025	0.025	0.025	0.072	0.015
NO3+NO2-N (mg/L)	11	0.161	0.150	0.025	0.394	0.025	0.310	0.025	0.394	0.135
Na (mg/L)	11	6.353	6.572	4.097	8.400	4.979	7.174	4.097	8.400	1.326
PO4-P (mg/L)	11	0.007	0.005	0.005	0.014	0.005	0.010	0.005	0.014	0.004
SO4 (mg/L)	11	1.482	1.500	1.300	1.500	1.500	1.500	1.300	1.500	0.060
pH (pH units)	11	7.105	7.825	4.818	8.300	5.578	8.043	4.818	8.300	1.321

Table 4.37: PAI results for 11_Mutshindudi

IUA	Upper Luvuvhu/Mutale	Water quality points	
River & Quat	Mutshundudi (A91G)	RC	
EWR site	11-Mutshindudi	PES	A9H025Q01 (2008-2018) n= 10
Confidence assessment	Moderate - High		
Water quality constituents		PES value	Category
Nutrients	PO_4-P (mg/l) median	0.005	0
	TIN (mg/l) median	0.175	0
Physical variables	pH (5th and 95th percentiles)	4.8 – 8.3	4
	T (°C) May 2023	21.75	2
	DO (mg/l) *May 2023*	9.86 mg/l / 118.9	2
	Turbidity (NTU)	No data	2
	EC (mS/m)	15.5	0
Response variables	SASS (ASPT) score	6.8	
Overall site classification (from PAI)		**B/C** (81.8%)	

The salinity at 11_Mutshindudi was low and there was no trend for Electrical Conductivity, a decreasing trend for nitrogen and a positive trend for orthphospates (**Figure 4.14**).

There were negative relationships between flow, Electrical Conductivity and PO_4-P (**Figure 4.15**), and a positive relationship with NO_2+NO_3-N, due to leaching during wet periods.

Average monthly water temperatures (°C) at 11_Mutshindudi are given in **Table 4.38**.

Table 4.38: Average monthly water temperatures at 11_Mutshindudi

Calendar month											
J	F	M	A	M	J	J	A	S	O	N	D
20.6	20.6	20.0	18.9	17.8	16.2	16.7	17.3	18.9	20.0	20.0	20.6

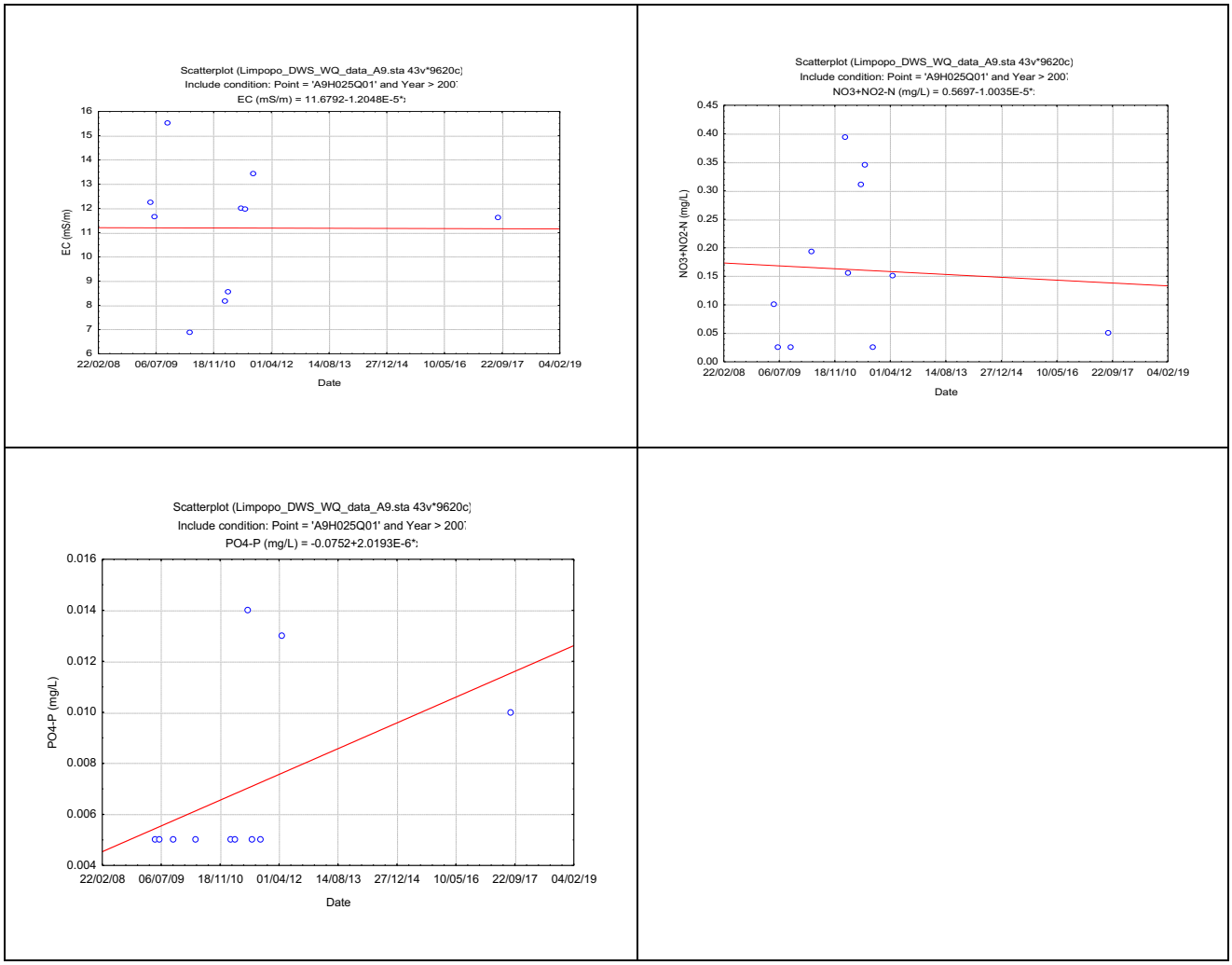


Figure 4.14: Time series plots of EC, NO2+NO3-N and PO4-P for 11_Mutshindudi

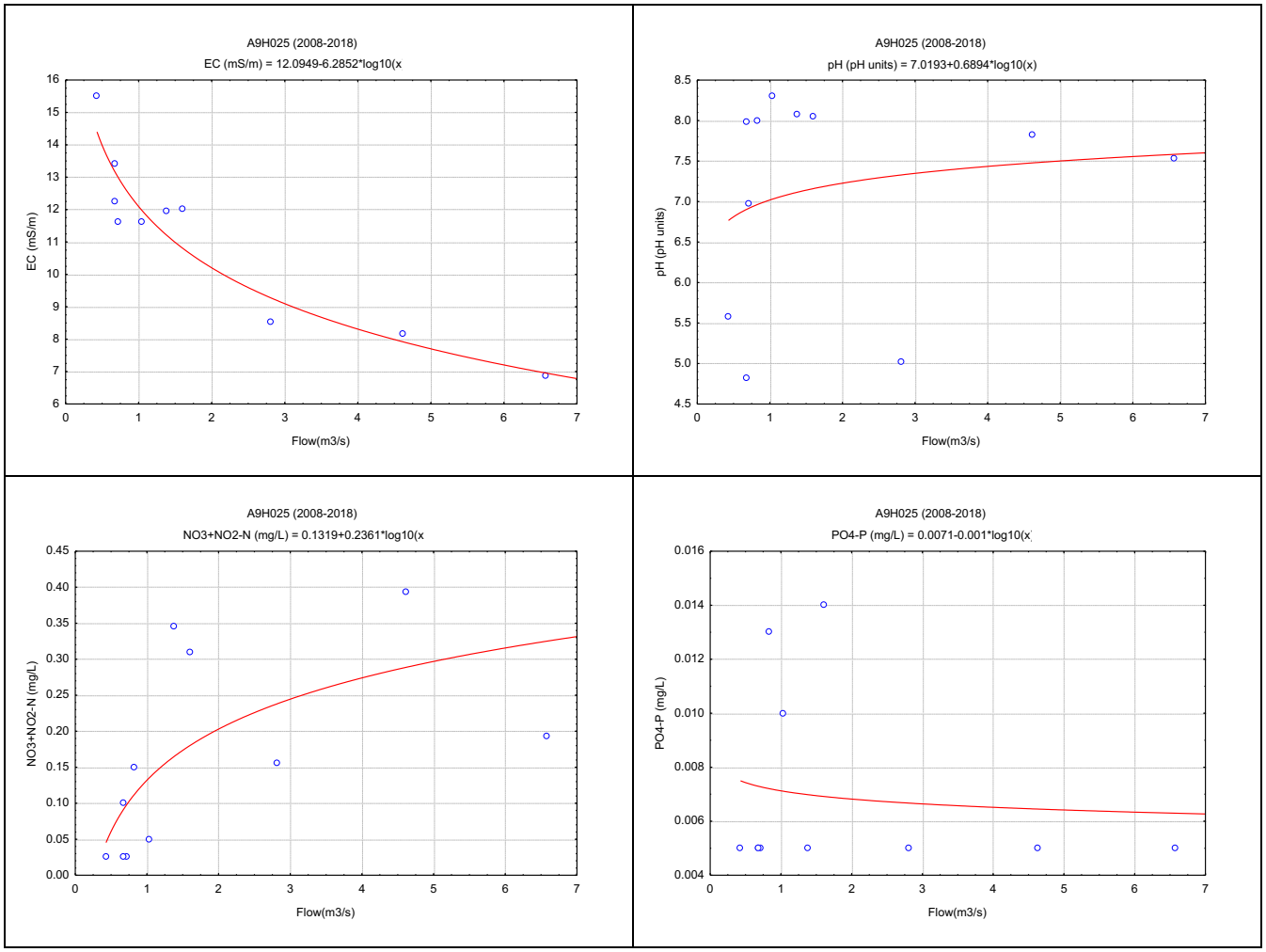


Figure 4.15: Relationship between flow, EC, pH NO2+NO3-N, and PO4-P at 11_Mutshindudi

4.2.3.12 12_Luvuvhu

The closest DWS water quality sampling point was A9H012Q01 (Mhingas on Luvuvhu River) where 617 samples have been collected from 1988 to 2018. Data from 2008-2018 were used for the summary statistics (**Table 4.39**).

The water quality was in a **B** category (**Table 4.40**).

Table 4.39: Water quality summary statistics for 12_Luvuvhu

A9H012Q01	N	Mean	Median	Min	Max	25%tile	75%tile	5%tile	95%tile	Std.Dev.
Ca (mg/L)	87	9.088	8.727	5.45	15.01	7.801	10.240	6.500	13.067	1.916
Cl (mg/L)	90	10.59	10.206	6.94	16.70	8.948	11.946	8.054	14.500	2.095
EC (mS/m)	94	14.82	14.805	9.30	20.70	13.700	16.360	10.430	17.700	2.151
Mg (mg/L)	88	6.004	6.002	2.60	8.954	5.385	6.923	3.353	7.900	1.325
NH_4-N (mg/L)	95	0.048	0.050	0.02	0.197	0.025	0.050	0.025	0.106	0.030
NO_3+NO_2-N (mg/L)	93	0.147	0.123	0.02	0.623	0.050	0.222	0.025	0.349	0.119
Na (mg/L)	75	8.348	8.238	2.60	14.40	7.506	9.393	5.134	11.200	1.877
PO_4-P (mg/L)	94	0.017	0.010	0.005	0.258	0.005	0.011	0.005	0.056	0.033
SO_4 (mg/L)	91	1.709	1.500	0.60	16.50	1.500	1.500	0.600	2.700	1.813
pH (pH units)	94	7.940	7.986	7.20	8.582	7.763	8.119	7.400	8.300	0.271

Table 4.40: PAI results for 12_Luvuvhu

IUA	Upper Luvuvhu/Mutale	Water quality points	
River & Quat	Luvuvhu (A91H)	RC	
EWR site	12_Luvuvhu	PES	A9H012Q01 (2008-2018). N = 94 for EC
Confidence assessment	Moderate to high		
Water quality constituents		PES value	Category
Nutrients	PO_4-P (mg/l)	0.010	1
	TIN (mg/l)	0.173	0
Physical variables	pH	7.4-8.3	1
	T (°C) May *2023*	23.21	1
	DO (mg/l) *May 2023*	8.8 /109.1	1
	Turbidity (NTU)	No data	2
	EC (mS/m)	17.7	0
Response variables	SASS (ASPT) score	6.0	
Overall site classification (from PAI)		**B** (85.5%)	

Salinity was low with a weak negative trend and there were weak positive relationships for nutrients (**Figure 4.16**).

There were negative relationships between flow, EC and pH (**Figure 4.17**) because of dilution in the wet season and positive relationships with nutrients because of agricultural and urban runoff.

Average monthly water temperatures (°C) at 12_Luvuvhu are given in **Table 4.41**.

Table 4.41: Average monthly water temperatures at 12_Luvuvhu

Calendar month											
J	F	M	A	M	J	J	A	S	O	N	D
20.6	20.6	20.0	18.9	17.8	16.2	16.7	17.3	18.9	20.0	20.0	20.6

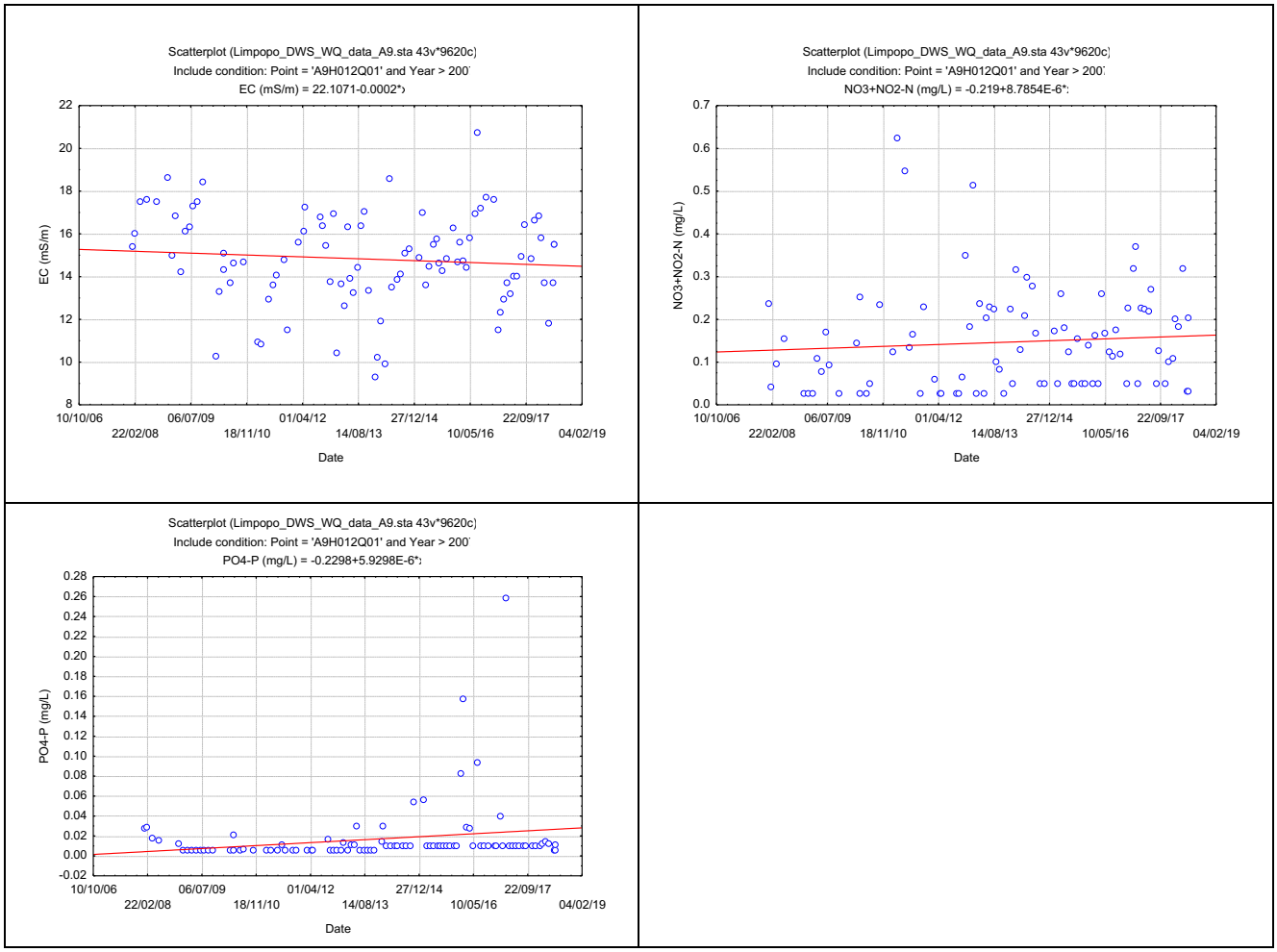


Figure 4.16: Time series plots of EC, NO2+NO3-N and PO4-P for 12_Luvuvhu

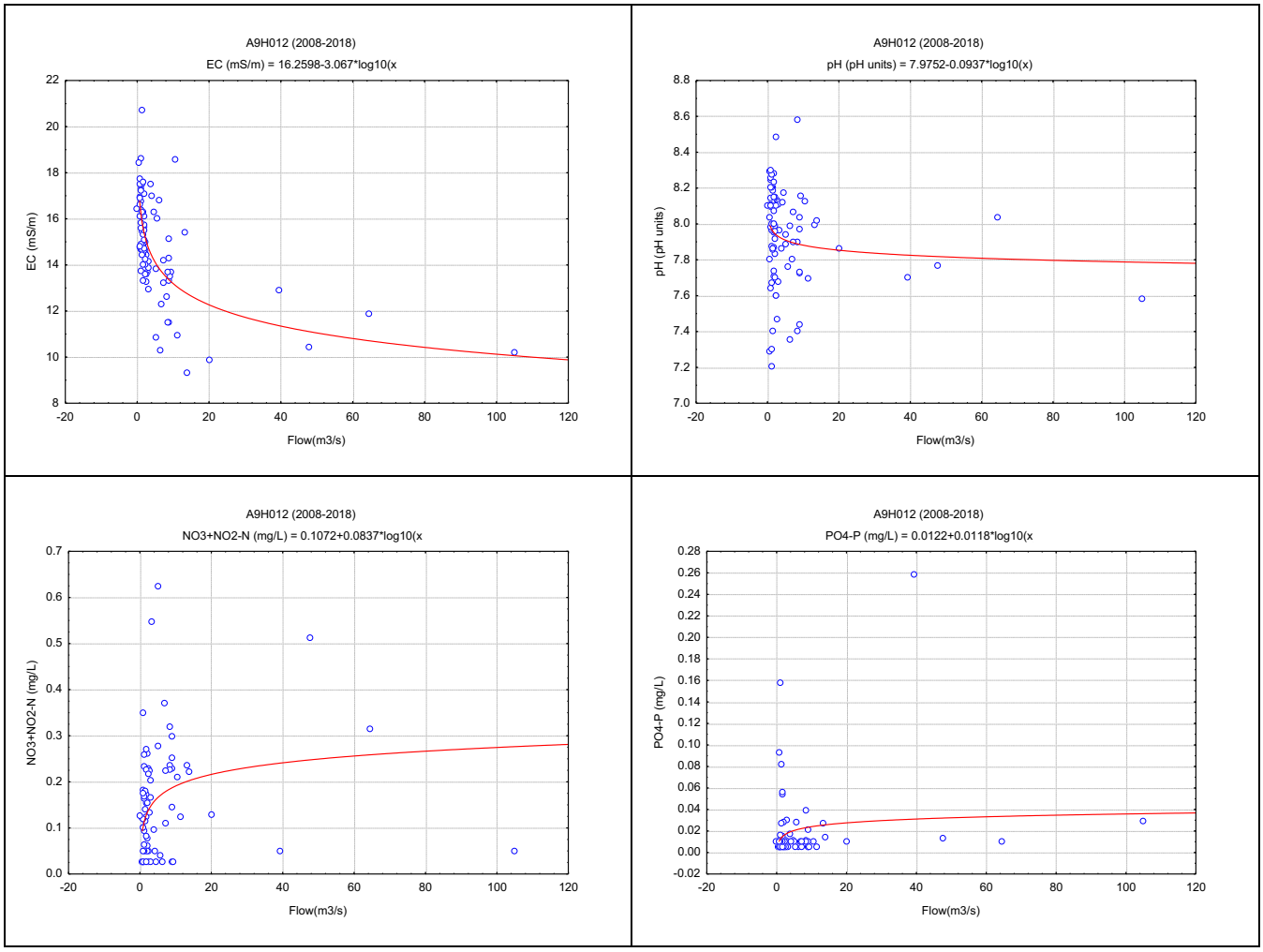


Figure 4.17: Relationship between flow, EC, pH, NO2+NO3-N, and PO4-P at 12_Luvuvhu

4.2.3.13 13_Mutale1

The closest DWS water quality monitoring site was WMS A92_188507 - Tshandama Tengwe S 255 MT Bridge 2 km from the Tshandama Tribal Office near Studam on the Mutale River, where 118 samples have been collected from 2005 – 2017. Data from 2008 to 2017 were used for the summary statistics (**Table 4.42**).

The water quality was in a **B** category (**Table 4.43**).

Table 4.42: Water quality summary statistics for 13_Mutale1

188507	N	Mean	Median	Min	Max	25%tile	75%tile	5%tile	95%tile	StdDev
Ca (mg/l)	26	3.17	3.26	0.50	4.64	3.00	3.73	0.89	4.54	1.05
Cl (mg/l)	30	7.35	7.00	3.60	17.00	6.40	7.78	4.78	10.55	2.37
EC (mg/l)	35	6.47	6.48	2.60	14.00	5.56	7.50	3.14	7.95	1.92
Mg (mg/l)	28	2.21	2.70	0.50	3.63	1.04	3.02	0.50	3.52	1.12
Na (mg/l)	30	4.70	4.90	0.50	12.31	4.21	5.13	1.34	6.13	1.98
NH4_N (mg/l)	5	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.00
NO3+NO2-N (mg/l)	11	0.52	0.20	0.05	2.69	0.17	0.48	0.05	1.85	0.77
pH	34	7.12	7.20	5.60	8.74	6.83	7.40	6.46	7.61	0.51
PO4_P (mg/l)	21	0.33	0.05	0.02	5.20	0.05	0.20	0.02	0.20	1.12
SO4 (mg/l)	32	5.43	1.57	0.50	61.00	1.47	5.00	0.50	18.85	11.26

Table 4.43: PAI results for 13_Mutale1

IUA	Lower Luvuvhu	Water quality points	
River & Quat	Mutale (A92B)	RC	
EWR site	13_Mutale1	PES	188507 - Tshandama Thengwe S 255 MT Bridge 2 km to Tshandama Tribal Office near Studam on Mutale River (2008-2017) N=35 for EC
Confidence assessment	Moderate to high		
Water quality constituents		PES value	Category
Nutrients	PO_4-P (mg/l) median	0.050	3
	TIN (mg/l) median	0.250	2
Physical variables	pH 5th and 95th percentiles	6.5 – 7.6	1
	T (°C) May 2023	22.24	1
	DO (mg/l) *May 2023*	8.65 mg/l / 105.99%	1
	Turbidity (NTU)	No data	3
	EC (mS/m) 95th percentile	17.2	0
Response variables	SASS (ASPT) score	6.2	
Overall site classification (from PAI)		**B** (83.6%)	

There was a weak decreasing trend with Electrical Conductivity, a weak increasing trend with nitrogen, and a weak decreasing trend with orthphospates (**Figure 4.18**).

There were no observed hydrological data to examine relationships to flow.

Average monthly water temperatures (°C) at 13_Mutale1 are given in **Table 4.44**.

Table 4.44: Average monthly water temperatures at 13_Mutale1

Calendar month											
J	F	M	A	M	J	J	A	S	O	N	D
21.7	21.1	20.6	20.0	17.8	16.2	16.2	17.3	18.9	20.6	20.6	21.7

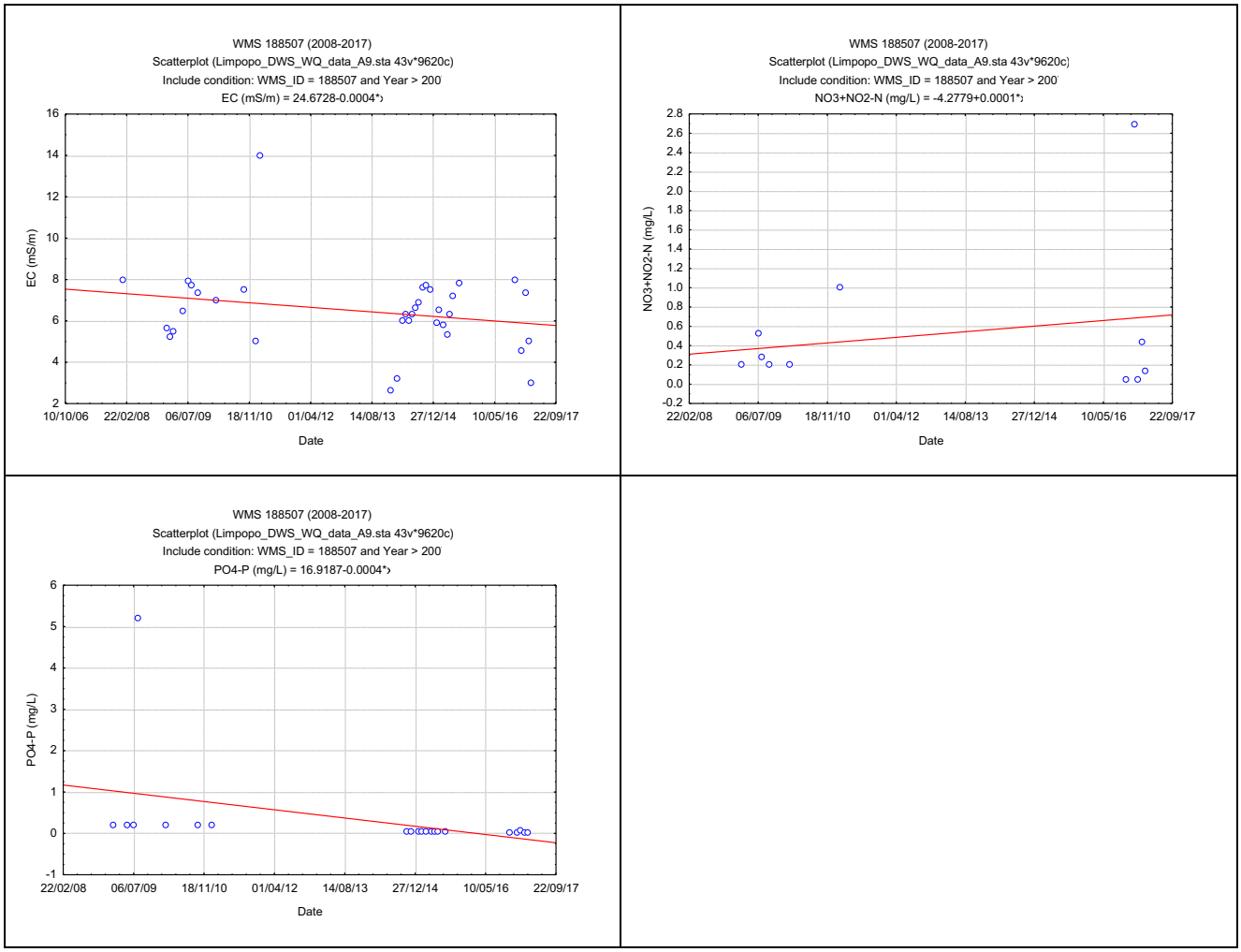


Figure 4.18: Time series plots of EC, NO2+NO3-N and PO4-P for 13_Mutale1

4.2.3.14 14_Mutale2

The closest DWS water quality sampling site was A9H013Q01 (Mutale Bend Kruger National Park) where 174 samples have been collected from 2003 and 2018. Data from 2008 and 2018 were used for the summary statistics **(Table 4.45).**

The water quality was in a **B** category (**Table 4.46**).

Table 4.45: Water quality summary statistics for 14_Mutale2

A9H013Q01	N	Mean	Median	Min	Max	25%tile	75%tile	5%tile	95%tile	Std.Dev.
Ca (mg/L)	57	7.686	7.640	1.682	15.980	5.046	9.142	2.959	15.400	3.510
Cl (mg/L)	57	16.937	15.793	3.837	35.062	11.275	20.866	8.723	31.181	7.148
EC (mS/m)	57	15.017	14.800	6.840	28.072	9.990	18.300	7.870	26.440	5.634
Mg (mg/L)	57	5.137	4.717	1.715	12.300	3.272	6.391	1.800	10.400	2.536
NH4-N (mg/L)	55	0.055	0.050	0.025	0.541	0.025	0.053	0.025	0.122	0.072
NO3+NO2-N (mg/L)	55	0.067	0.040	0.005	0.374	0.025	0.067	0.005	0.323	0.084
Na (mg/L)	51	11.367	9.823	3.000	32.349	7.391	14.466	4.100	22.562	6.124
PO4-P (mg/L)	55	0.015	0.010	0.005	0.148	0.006	0.013	0.005	0.066	0.023
SO4 (mg/L)	56	2.471	1.578	0.375	8.545	1.291	3.000	0.600	6.512	1.917
pH (pH units)	57	7.836	7.863	7.017	8.400	7.632	8.033	7.373	8.326	0.280

Table 4.46: PAI results for 14_Mutale2

IUA	Lower Luvuvhu	Water quality points		
River & Quat	Mutale (A92D)	RC		
EWR site	14_Mutale2	PES	A9H013Q01 (2008-2018). N = 57	
Confidence assessment	Moderate to high			
Water quality constituents			PES value	Category
Nutrients	PO_4-P (mg/l)		0.010	1
	TIN (mg/l)		0.090	0
Physical variables	pH		7.4 – 8.3	1
	T (°C) May 2023		23.18	2
	DO (mg/l) *May 2023*		8.37 mg/l / 100.2%	1
	Turbidity (NTU)		No data	2
	EC (mS/m)		26.44	0
Response variables	SASS (ASPT) score		5.7	
Overall site classification (from PAI)			**B** (84.5%)	

The Salinity (EC) data were scattered but do show a positive trend for nutrients (**Figure 4.19**).

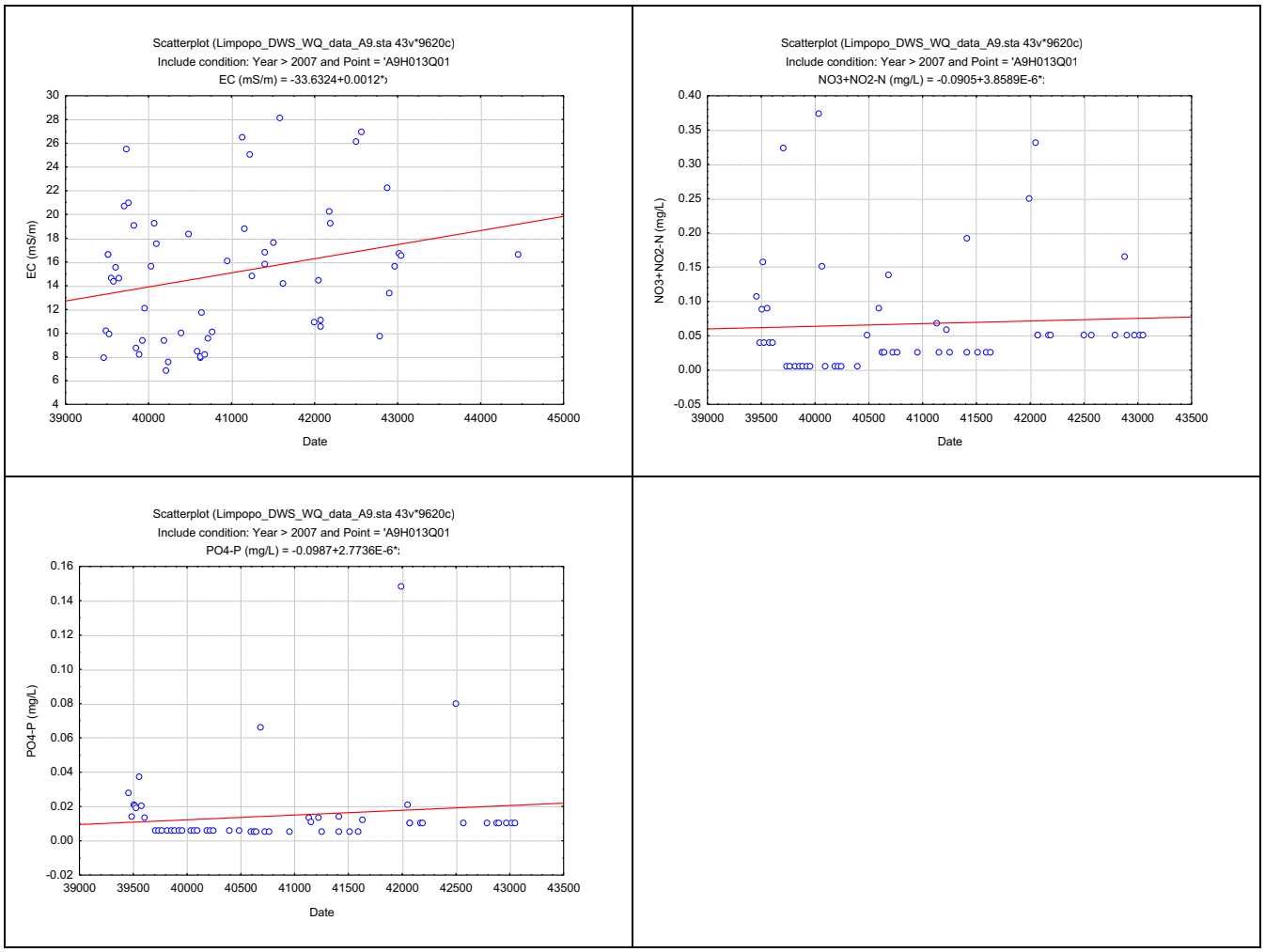


Figure 4.19: Time series plots of EC, NO2+NO3-N and PO4-P recorded for 14_Mutale2

There were good relationships between flow, Electrical Conductivity and pH and that between flow and nutrients was weak (**Figure 4.20**).

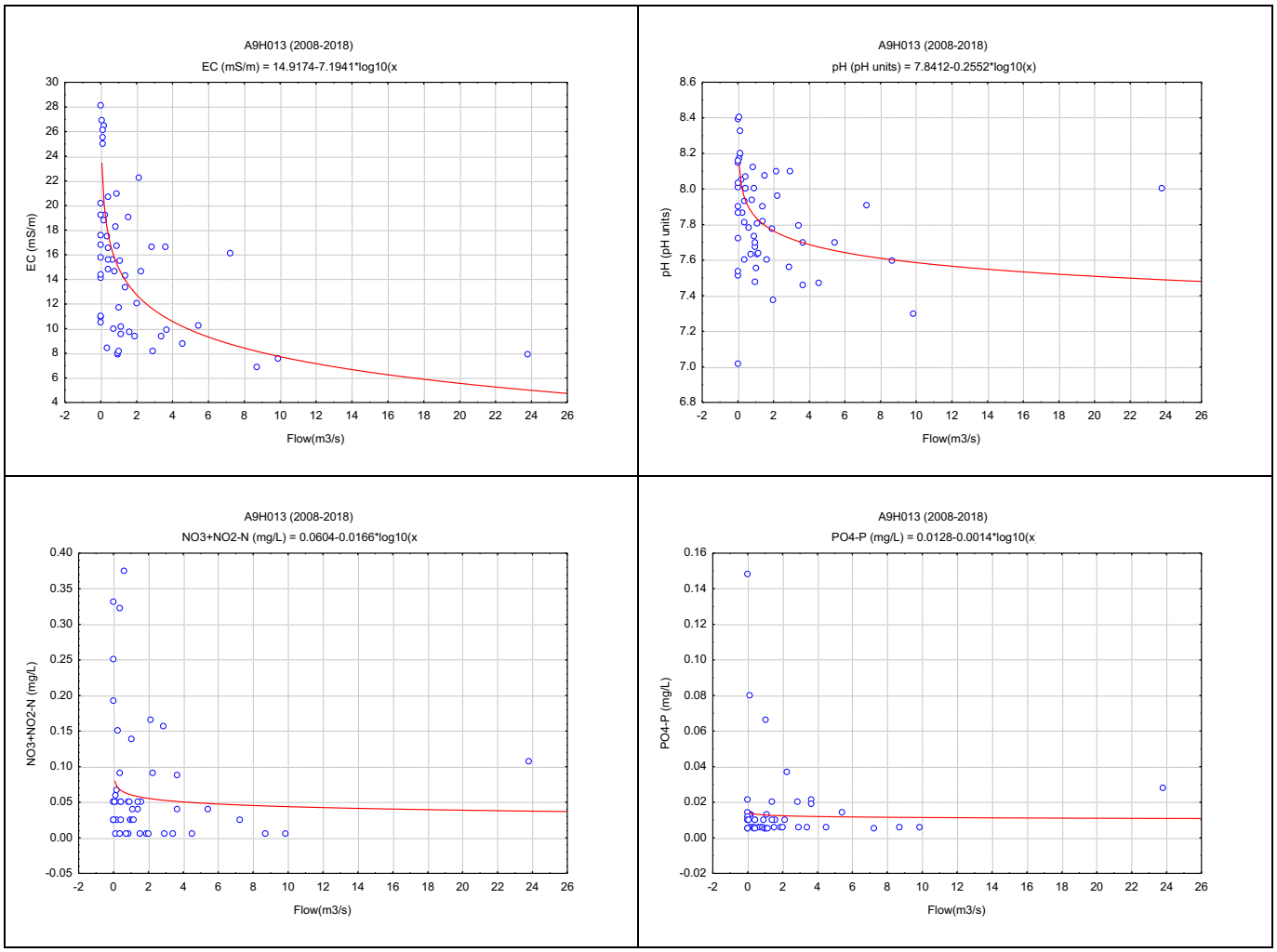


Figure 4.20: Relationships between flow, EC, NO2+NO3-N, PO4-P and pH at 14_Mutale2

Average monthly water temperatures (°C) at 11_Mutshindudi are given in **Table 4.47**.

Table 4.47: Average monthly water temperatures at 11_Mutshindudi

Calendar month											
J	F	M	A	M	J	J	A	S	O	N	D
28.5	27.6	26.7	25.8	22.2	19.5	19.5	21.3	24.0	25.8	27.6	28.5

4.3 Water quality indicators

A list of water quality indicators and the reason for their selection is given in **Table 4.48.**

Table 4.48: Water quality indicators and reasons for their selection

Indicator	Reasons for selection	EWR sites													
		1_Lephalala	2_Rietfontein	3_Olifantspruit	4_Mogalakwena1	5_Mogalakwena2	6_Kolope	7_Sand	8_Nzhelele	9_Ṅwanedi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale1	14_Mutale2
Water clarity	Water clarity is related to suspended sediment concentrations and turbidity of the water.	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Electrical conductivity (EC)	EC is an indicator of the salinity or concentration of dissolved salts. It is affected by the geology of a catchment and mining, irrigation return-flows, industrial effluents, runoff from urban areas and urban sprawl.	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Water temperature	Temperature is important for the survival of biota such as fish and invertebrates, it affects biological processes and the solubility of dissolved oxygen, metals and toxic substances.	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Total Inorganic nitrogen (TIN)	High nutrient concentrations have a significant impact on the structure and functioning of biotic communities because they stimulate growth of algae and aquatic plants. Nitrogen from fertilisers leaches more readily from soils than orthphospates.	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Orthophosphate (PO_4-P)		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dissolved oxygen	The maintenance of adequate dissolved oxygen (DO) concentrations is critical for the survival and functioning of the aquatic biota because it is required for the respiration of all aerobic organisms. The DO concentration provides a useful measure of the health of an aquatic ecosystem.	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Biocides	Biocides are chemical substances, mixtures, or microorganisms intended to control the growth of pest organisms.	X	X	X	X	X	X	X	X	X	X	X	X	X	X

4.3.1 Water clarity

Water clarity is related to the suspended sediment concentrations and turbidity of the water.

The immediate visual effect of a change in turbidity is a change in water clarity. An increase in turbidity or suspended sediments affects light penetration, which may have far reaching consequences for aquatic biota (Dallas and Day 2004).

The natural seasonal variations in rivers often include changes in turbidity and are dependent on the hydrology and geomorphology of the region (Dallas and Day 2004).

Water clarity is directly related to flow because higher flows wash over the land and also erode river banks, both increase suspended sediments. As flow velocities slow down during the dry season, suspended sediments settle. Very fine silt and clay particles may remain behind in the water as colloidal particles. An increase in salinity during the dry season can cause flocculation of suspended particles causing them to drop out of suspension, which will again resuspend during high flow.

Increases in turbidity or changes in water clarity can be a result of natural processes or other anthropogenic activities. If turbidity increases due to human activities are infrequent, and due to natural floods as an example, the stream community may tolerate the temporary increases. However, continuous higher turbidity levels may have serious consequences for the riverine biota. Light penetration is reduced, primary production decreases and food availability to organisms higher in the food chain is less. Suspended sediments that settle out may also smother and abrade small organisms. Community composition may change, depending on which organisms can tolerate or adapt to the habitat changes. Predator-prey interactions can be affected by the impairment of visually-hunting predators (Dallas and Day 2004).

Few studies on turbidity effects have been conducted in South Africa, primarily because turbid rivers are fairly common in this country and are thus not considered problematic (Dallas and Day 2004).

Water clarity was linked to the geomorphology indicator, Clay silt FPOM supply [All seasons] (**Table 4.49**).

Table 4.49: The reasons for, and relationship between, indicators linked to water clarity

Linked indicator	Reasons	Relationship
Clay silt FPOM supply [All seasons]	Water clarity is directly related to the amount of clay, silt and FPOM in the water.	More Clay silt FPOM = less water clarity.

4.3.2 Electrical conductivity

One of the major descriptors of the "quality" of a water sample is the total amount of material dissolved in it. This property of water is commonly measured in one of three ways: as total dissolved solids (TDS), as electrical conductivity (EC), or as salinity, all of which correlate closely in most waters.

In this study, EC was selected as an indicator of the salinity of the water, the amount of TDS, or the total amount of dissolved ions in the water. The effects of the TDS are governed by the constituent inorganic salts on the metabolism of aquatic organisms. Secondary effects include those on water chemistry, which in turn affect the fate and impact of other chemical constituents or contaminants on the aquatic environment.

Aquatic biota have very distinctive salinity tolerances and it is species-specific (Palmer et al. 2004). Some fauna and flora are able to cope with varying degrees of salinity. Usually these coping mechanisms have a threshold beyond which extremely variable salinity conditions can directly and indirectly cause changes to the physical and biological aquatic environments. The main concern for aquatic organisms associated with salinity is osmotic stress, when cells of the organisms have either a lack of water or an excess of ions (or both) that can result in a range of toxic effects.

Freshwater invertebrates can also be adversely affected by salinity as they are hyper-osmotic regulators. Hence, they are incapable of maintaining body fluid solute concentrations below that of the water they live in. If the salinity of their environment is increased above a threshold level below which they can maintain a constant ionic concentration, they take up increasingly more ions. They then loose more water from their cells, until they no longer function properly, and the organism dies. For invertebrates, factors such as degree of acclimation, life stage and temperature can influence their sensitivity to salinity increases.

Fish fauna are known to have coping mechanisms to deal with varying salinities in their surrounding environment, i.e. they use either hyper-osmotic (transport ions across gill surfaces) or hypo-osmotic regulation (loose water through gills) (Hart et al. 1991). A large proportion of fish species have marine origins and as a result have some inherent tolerance to salinity. Life stages can also affect tolerance capabilities as larval fish do not have adult osmoregulatory abilities, placing them at higher risk in varying salinity conditions (Palmer et al. 2004).

Electrical conductivity was linked to the following drivers (**Table 4.50**):

- Dry average daily volume [Dry season]
- Wet average daily volume [Flood season]
- Pressures affecting water quality [All seasons]

Table 4.50: The reasons for, and relationship between, indicators linked to Electrical Conductivity

Linked indicator	Reasons	Relationship
Dry average daily volume [Dry season]	Salinity is inversely related to flow due to dilution. Salinity increases during the dry season as less water is available for dilution, and as salts are concentrated in smaller volumes of water. This is especially the case at very low flows when elevated salt concentrations can occur.	More dry season volume = lower salinity.
Wet average daily volume [Flood season]		More wet season volume = lower salinity.
Pressures affecting water quality [All seasons]	Salinity increases with more irrigated agriculture because of increases in irrigation return flows; with more urban and peri-urban areas because of more urban runoff, grey water discharges, and wastewater effluents, and with more mining and industrial development due to effluent discharges and stormwater runoff.	More pressures affecting water quality = higher salinity.

4.3.3 Water temperature

Southern Africa has been identified as a 'critical region' of water stress and existing anthropogenic stresses on freshwater ecosystems are substantial. Water temperature, together with flow, are master variables driving river condition (Dallas and Rivers-Moore 2019).

The thermal characteristics of rivers are dependent on various hydrological, climatic and structural features of the region and river basin. Rivers exhibit daily and seasonal temperature patterns, in addition to changes along the longitudinal length. All organisms have a temperature or range of temperatures at which optimal growth, reproduction and general fitness occur. Changing water temperatures puts aquatic organisms under stress and may be lethal. Anthropogenic causes of temperature changes in river systems include thermal pollution, stream regulation and changes in riparian vegetation. An increase in water temperature decreases oxygen solubility and may also increase the toxicity of certain chemicals. Many life history traits are cued into temperature, for example, temperature is the cue for fish migration and breeding. Temperature changes affect metabolic processes and life cycle patterns by altering times of reproduction, rates of development and emergence times of aquatic organisms (Dallas and Day 2004).

The drivers of water temperature are solar radiation and the upstream water temperature. The insulators which influence the rate of heat exchange with the atmosphere are river width and depth, topographic shade, shading by riparian vegetation, and upland vegetation. The buffers that store heat in the system and integrate the variation in flow and temperature over time, are geology, groundwater depth, water travel time and channel morphology (Dallas and Rivers-Moore 2019).

Water temperature was linked to the following hydrological drivers **(Table 4.51):**

- Dry average daily volume [Dry season]
- T1 average daily volume [T1 season]
- Wet average daily volume [Flood season]
- T2 average daily volume [T2 season]

Table 4.51: The reasons for, and relationship between, indicators linked to Water Temperature

Linked indicator	Reasons	Relationship
Dry average daily volume [Dry season]	Water temperature increases as discharge decreases, and the magnitude of diurnal variation is typically inversely proportional to flow rate.	Higher daily volumes = lower water temperatures.
T1 average daily volume [T1 season]		
Wet average daily volume [Flood season]		
T2 average daily volume [T2 season]		

4.3.4 Total inorganic nitrogen (TIN)

Various plant nutrients are required for plant growth and reproduction. Nitrogen and phosphorus are often responsible for excess plant growth from nutrient enrichment (eutrophication). Most nutrients are not toxic (except nitrite and ammonia), even in high concentrations (Dallas and Day 2004).

Climatic and catchment characteristics influence nutrient concentrations in rivers. Anthropogenic sources of nutrients may be point -sources (e.g. sewage treatment works or industry animal feeding lots) and/or nonpoint-sources (agricultural and urban runoff or atmospheric deposition). Fertilizers are significant contributors to eutrophication (Dallas and Day 2004).

Nitrogen occurs abundantly in nature and is an essential constituent of many biochemical processes. Inorganic nitrogen may be present in many forms including ammonia (NH_3^+), ammonium (NH_4^+), nitrites (NO_2^-) and nitrates (NO_3^-). When inorganic nitrogen enters a river, the nitrates are rapidly converted to organic nitrogen in plant cells. Nitrite is an intermediate in the conversion of ammonia to nitrate and is toxic. Un-ionised ammonia is also toxic and its toxicity increases as pH and temperature increase (Dallas and Day 2004). Ammonia toxicity is also affected by the concentrations of dissolved oxygen, carbon dioxide and total dissolved solids, and the presence of other toxicants, such as metal ions. The acute toxicity of ammonia to fish increases as dissolved oxygen decreases (DWAF 1996).

Total inorganic nitrogen was linked to the following drivers (**Table 4.52)**:

- Dry average daily volume [Dry season]
- Wet average daily volume [Flood season]
- Pressures affecting water quality [All seasons].

Table 4.52: The reasons for, and relationship between, indicators linked to Total Inorganic Nitrogen

Linked indicator	Reasons	Relationship
Dry average daily volume [Dry season]	Inorganic nitrogen concentrations increase with an increase in flow as fertiliser is leached from agricultural lands. The impacts are lower in areas dominated by dry-land agriculture.	Higher volumes = higher nitrogen concentrations.
Wet average daily volume [Flood season]	Inorganic nitrogen concentrations will increase with an increase in flow as fertiliser is leached from agricultural lands, and urban and peri-urban runoff increase. This is especially true in areas where irrigation agriculture intensifies during the wet season.	Higher volumes = higher nitrogen concentrations.
Pressures affecting water quality [All seasons]	Inorganic nitrogen concentrations are affected by land-use activities such as agriculture (leaching of nitrogen containing fertiliser from cultivated fields), urban developments (discharge of wastewater effluents high in N), runoff from concentrated agricultural sources (such as animal feedlots, aquaculture, crocodile farms) and urban stormwater runoff.	More pressures affecting water quality = higher nitrogen concentrations.

4.3.5 Orthophosphate (PO_4-P)

High nutrient concentrations in aquatic ecosystems often cause excessive growth of nuisance plants that can impair water quality (Walmsley 2000). Algae and aquatic macrophytes require about 20 different elements for plant growth and reproduction. However, the rate and extent of aquatic plant growth is dependent on the concentration and ratios present in the water. Plant growth is generally limited by the concentration of that nutrient that is present in the least quantity relative to the growth needs of the plant. This is known as the limiting nutrient concept and is the basis of eutrophication management policy. Phosphorus and nitrogen are often the limiting nutrients, but phosphorus is recognised as the fundamental cause of eutrophication (Walmsley 2000).

Orthophosphates occur in aquatic environments in numerous organic and inorganic dissolved forms. High concentrations can stimulate excessive growth of aquatic plants and algae. High concentrations of phosphorus are likely to occur in water that receives sewage effluent and leaching or runoff from cultivated land (Dallas and Day 2004).

Orthophosphate was linked to the following drivers (**Table 4.53**):

- Dry average daily volume [Dry season]
- Wet average daily volume [Flood season].

Table 4.53: The reasons for, and relationship between, indicators linked to Orthophosphate.

Linked indicator	Reasons	Relationship
Dry average daily volume [Dry season]	There is a weak positive relationship between P and flow as P is transported mostly adhered onto suspended sediment particles.	Higher volumes = lower concentrations of P.
Wet average daily volume [Flood season]		

4.3.6 Dissolved oxygen

The maintenance of adequate dissolved oxygen (DO) concentrations is critical for the survival and functioning of the aquatic biota because it is required for the respiration of all aerobic organisms. DO concentration provides a useful measure of river health (DWAF 1996).

In unpolluted surface waters, dissolved oxygen concentrations are usually close to saturation. The saturation concentration for DO is lower at higher water temperatures (DWAF 1996). Typical saturation concentrations at sea level, and at TDS values below 3 000 mg/L are: 12.77 mg/L at 5 °C; 10.08 mg/L at 15 °C; 9.09 mg/L at 20 °C.

There is a natural diel variation (24-hour cycle) in dissolved oxygen associated with the 24-hour cycle of photosynthesis and respiration by aquatic biota. Concentrations decline through the night to a minimum near dawn, then rise to a maximum by mid-afternoon. Seasonal variations arise from changes in temperature and biological productivity (DWAF 1996).

Reduction in the concentration of dissolved oxygen can be caused by several factors such as the resuspension of anoxic sediments, as a result of river floods or dredging activities; the presence of oxidizable organic matter, either of natural origin (detritus) or originating in wastewater discharges; the amount of suspended material in the water affects the saturation concentration of dissolved oxygen, either chemically, through the oxygen-scavenging attributes of the suspended particles, or physically through reduction of the volume of water available for solution (DWAF 1996, Dallas and Day 2004).

Dissolved oxygen concentrations can be increased by natural diffusion of gaseous oxygen from the atmosphere into water. Diffusion continues until the saturation concentration is reached. The rate of increase of dissolution of oxygen can be accelerated if turbulence of the water increases, causing entrainment of air from the atmosphere.

The extent to which organisms are affected by a decrease in dissolved oxygen is determined by its dependence on water. The oxygen requirements of fish and invertebrates varies per species, with life stages and with different life processes and size. Juveniles are more sensitive than adults to physiological stress during oxygen depletion, and in particular to secondary effects such as increased vulnerability to predation and disease. Prolonged exposure to sublethal, low oxygen concentrations may lead to changes in behaviour, blood chemistry, growth rate and food intake (Dallas and Day 2004).

Dissolved oxygen was linked to the following drivers (**Table 4.54**):

- Dry minimum 5-day flow [Dry season]
- Wet season 5-day flow [Flood season]
- Water temperature [All season].

Table 4.54: The reasons for, and relationship between, indicators linked to Dissolved Oxygen

Linked indicator	Reasons	Relationship
Dry minimum 5-day Q [Dry season]	Lower flows during the dry season can result in lower DO concentrations in rivers and streams because (1) particulate organic matter (POM) deposited in streams and rivers settle out, consuming oxygen during their decomposition, and (2) there can be less turbulent flows leading to lower aeration rates.	Lower dry season Q = lower DO.
Wet season 5-day Q [Flood season]	Higher flows during the wet season can result in higher DO concentrations in rivers and streams because (1) particulate organic matter (POM) remains in suspension as it is transported in a downstream direction, and (2) more turbulent flows can lead to higher aeration rates.	Lower wet season Q = lower DO.
Water temperature [All season]	Water temperature effects DO solubility. Higher temperatures reduce the solubility of dissolved oxygen in water, decreasing its concentration and thus its availability to aquatic organisms.	Higher water temperature = lower DO.

4.3.7 Biocides

Biocides are chemical substances, mixtures, or microorganisms intended to control other pest organisms. Biocidal products are used to protect people and animals, preserve consumer goods, stop pests like insects or rodents, and control viruses, bacteria, and fungi through a chemical or biological action. Common examples are disinfectants, wood preservatives and insect repellents.

Agrochemicals and biocides, also known as pesticides, are chemicals that kill living organisms and are used in the control of pests (Griffen *et al.* 2014). The most commonly used biocides are herbicides, fungicides and insecticides (Dallas and Day 2004). South Africa is a significant user of pesticides in agriculture, suggesting that the potential for non-point source environmental contamination is high. The type of pesticide and usage pattern is variable across South Africa, depending on climatic conditions and crop types, e.g. fungicides are used widely in the wetter grape-, fruit- and wheat-producing areas of the Western Cape, but herbicides are more prevalent in the maize-growing areas. Pesticide use also occurs as vector control in public health, commercial pest control, domestic use, and in selected industrial or food-processing technologies (e.g. dried fruit and timber-related production activities). However, the infrastructure to monitor and control pesticide use is also poorly developed. Data on pesticides are sparse with previous results constrained by high detection limits masking significant levels of pesticides. This is of particular significance as endocrine disrupting effects occur at concentrations far lower than other toxic effects.

The factors determining runoff and leaching of biocides include the physiochemical properties (e.g. water solubility, soil mobility and pesticide persistence) of the pesticide and soil (e.g. texture, organic matter content, depth of the soil horizon, erosion potential, pH and microbial content) (London *et al.* 2000, Dabrowski 2015). Of primary concern, however, is the persistence and accumulation of pesticides in food chains, and the role of certain pesticides in causing reproductive failure and endocrine system abnormalities in species not intended as their target.

Persistent Organic Pollutants (POPs) are highly stable, toxic, hydrophobic and lipophilic compounds, with the ability to accumulate in biological tissues. Many POPs can be lethal in high concentrations, but their greatest detrimental effects lie in their chronic toxicity, leading to dermal effects, liver and kidney disease, defects of the immune-, reproductive-, nervous-, and endocrine systems and even cancer. Because of their lipophilic nature, these pollutants tend to accumulate in matrices rich in organic matter, such as soil, sediment and biota, and can bio-accumulate in food chains. Global concerns about POPs lead to the United Nations Environment Programme (UNEP) initiating the Stockholm Convention on Persistent Organic Pollutants (SCPOPs) in May 1995. The convention is an international, legally binding treaty initially focussing on the reduction and elimination of the twelve most harmful POPs. These POPs included certain chlorinated pesticides (aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex and toxaphene), two groups of industrial chemicals – hexachlorobenzene (HCB) and polychlorinated biphenyls (PCB), and unintentional combustion by-products known as polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF). Later more chemicals were added to the list. South Africa played a major role in the negotiations and implementation of the SCPOPs. Research in South Africa has shown that very little is known about levels of POPs and PAHs or distribution patterns.

Biocides were linked to the following drivers (**Table 4.55**):

- T1 Class 3 flood [T1 season]
- T1 Class 4 flood [T1 season]
- 1:2 Class 5 flood [Flood season]
- Pressures affecting water quality [All season]

Table 4.55: The reasons for, and relationship between, indicators linked to Biocides

Linked indicator	Reasons	Relationship
T1 Class 3 flood [T1 season]	Agrochemicals (pesticides and herbicides) enter water courses from spraydrift, runoff (often adhered onto sediment particles) and leaching from the soil. The first runoff after a long, dry period of pesticide application often results in the highest pesticide input (Dabrowski et al. 2001, Dabrowski 2015).	More floods = more biocides.
T1 Class 4 flood [T1 season]		
1:2 Class 5 flood [Flood season]		
Pressures affecting water quality [All season]	Biocides are generally applied to agricultural lands to control pest insects and unwanted pest plants.	More pressures affecting water quality = more biocides.

4.4 Status and trends

Trends are typically described as an increasing/positive trend (i.e., quality becoming poorer due to an increase in concentrations), a neutral/stationary trend (i.e., stable trend with no significant change in concentrations), or a decreasing/negative trend (i.e., quality becoming better due to a decrease in concentrations).

Where long-term water quality data records existed dating back to the 1970s or 1980s, the trends were quantified, and probable causes identified. However, where data records were short, or no monitoring data was available, a qualitative assessment was done by considering changes in land-use over time and the impacts these changes would have had on water quality.

Estimates of the improvement in water quality of natural compared to PES (2022) are given in **Table 4.56**. Assuming that the current water quality state was 100%, it was assumed that under natural conditions (*c.* 1900) the quality would have been better than present day. i.e. values were lower than 100%. The relative improvement in quality (% improvement) is dependent on the magnitude of change to present day in flow, land use and other anthropogenic changes.

With little historical data the trends were interpolated from 1900 to 2000, with deterioration being slower from 1900 to 1960 and faster from 1960 to 2000 (**Table 4.56**).

Table 4.56: Estimates of changes in water quality as percentage relative to PES (2022)

Indicator	Years	1_Lephalala	2_Rietfontein	3_Olifantspruit	4_Mogalakwena1	5_Mogalakwena2	6_Kolope	7_Sand	8_Nzhelele	9_Ṅwaneḑi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale1	14_Mutale2
Clarity	1900	90	80	90	70	70	90	60	90	90	90	70	80	70	80
	1960	93	87	93	80	80	93	73	93	93	93	80	87	80	87
	2000	96	95	96	90	90	96	90	96	96	96	90	95	90	95
EC	1900	90	70	90	70	70	90	70	70	70	90	70	70	90	70
	1960	93	80	93	80	80	93	80	80	80	93	80	80	93	80
	2000	96	90	96	90	90	96	90	90	90	96	90	90	96	90
Temperature	1900	90	95	90	90	90	95	85	80	80	95	90	90	90	90
	1960	93	97	93	93	93	97	90	87	87	97	93	93	93	93
	2000	96	99	96	96	96	99	95	95	95	99	96	96	96	96
TIN	1900	70	95	80	90	90	95	80	90	90	95	80	70	90	90
	1960	80	97	87	93	93	97	87	93	93	97	87	80	93	93
	2000	90	99	95	96	96	99	95	96	96	99	95	90	96	96
PO_4-P	1900	70	95	80	90	90	95	80	90	90	95	80	70	90	90
	1960	80	97	87	93	93	97	87	93	93	97	87	80	93	93
	2000	90	99	95	96	96	99	95	96	96	99	95	90	96	96
DO	1900	95	95	95	95	95	95	95	90	90	95	95	95	95	95
	1960	97	97	97	97	97	97	97	93	93	97	97	97	97	97
	2000	99	99	99	99	99	99	99	96	96	99	99	99	99	99
Biocides	1900	95	95	90	80	80	100	80	80	80	95	90	80	90	90
	1960	97	97	93	87	87	100	87	87	87	97	93	87	93	93
	2000	99	99	96	95	95	100	95	95	95	99	96	95	96	96

4.4.1 Water clarity

Water clarity is related to the suspended sediment concentrations and turbidity of the water. When the flow velocity reduces, the suspended particles start to settle out often resulting in clear water (high clarity) during the low flow season. However, human activities such as the discharge of effluent high in turbidity, or dry-weather runoff from urban and peri-urban areas can maintain low water clarity throughout the low flow season.

Water clarity is relevant to all fourteen EWR sites.

The main anthropogenic drivers of the indicator status are:

- An increase in dryland irrigation and subsistence agriculture. This would increase the area of exposed soil and would promote washoff of suspended sediments into rivers during rain.
- An increase in sand mining. Sand mining and washing promotes erosion in the river channel that increases suspended sediment loads.
- An increase in urban areas and surrounding urban sprawl that increases urban stormwater runoff from hardened surface areas, and runoff from unpaved roads.
- An increase in deforestation and overgrazing that increases soil erosion and therefore increases suspended loads.
- An increase in mining (for example open cast mining or tailings dams) and quarry activities that increase suspended sediment loads during rain.
- Dams that trap sediments and the sediment hungry water released from dams.

Assuming that the current water clarity state was 100% in 2022, then (**Table 4.56**):

- 1_Lephalala, 3_Olifantspruit, 6_Kolope, 8_Nzhelele, 9_Ṅwaneḍi and 10_Latonyanda were 90% in 1900, 93% at 1960 and 96% at 2000 because the PES (2022) conditions were largely natural, or where dams on the Nzhelele and Ṅwaneḍi Rivers trapped sediments.
- 2_Rietfontein, 12_Luvuhvu and 14_Mutale were 80% in 1900, 87% in 1960 and 95% in 2000 due to moderate land-use changes upstream of these sites.
- 4_Mogalakwena1, 5_Mogalakwena2, 11_Mutshindudi, and 13_Mutale1 were 70% in 1900, 80% in 1960 and 90% in 2000 due to large changes in land-use upstream of the EWR sites.
- 7_Sand, was 60% in 1900, 73% in 1960 and 90% in 2000 due to large changes in land-use upstream of the EWR site.

4.4.2 Electrical conductivity

EC is an indicator of the salinity or concentration of dissolved salts in streams and rivers. It is affected by the geology of a catchment as well as mining, irrigation return-flows, industrial effluents, and runoff from urban areas and urban sprawl.

Electrical conductivity is relevant to all fourteen EWR sites.
The four main anthropogenic drivers of indicator status are:

- An increase in irrigation areas and irrigation return flows.
- An increase in mining and industrial activities.
- An increase in runoff from urban areas and urban sprawl.

- A decrease in flow due to abstractions, especially during the dry season, leads to less dilution of high salinity effluent streams, and a concentration of salts in pools as the water volume decrease due to evaporation losses.

Assuming that the current electrical conductivity state was 100% in 2022, then (**Table 4.56**):

- 1_Lephalala, 3_Olifantspruit, 6_Kolope, 10_Latonyanda and 13_Mutale1 would be 90% in 1900, 93% in 1960 and 96% in 2000 because the PES (2022) conditions are close to natural.
- 2_Rietfontein, 4_Mogalakwena1, 5_Mogalakwena2, 7_Sand, 8_Nzhelele, 9_Ṅwaneḍi, 11_Mutshindudi, 12_Luvuvhu, and 14_Mutale2 would be 70% in 1900, 80% in 1960 and 90% in 2000 due to large changes in land-use that affect EC.

4.4.3 Water temperature

Temperature is important for the survival of biota such as fish and invertebrates, it affects biological process rates, and it affects the solubility of dissolved oxygen, metals, and toxic substances.

Water temperature is relevant to all fourteen EWR sites.

The main anthropogenic drivers of indicator status are:

- A decrease in flow and water depth due to water abstractions for irrigation, domestic, mining and industrial water supply resulting in an increase in water temperature during low flow.
- An increase in suspended sediments restricts solar radiation into the water, resulting in cooler water.

Assuming that the current water temperature state was 100% in 2022, then (**Table 4.56**):

- 2_Rietfontein, 6_Kolope, and 10_Latonyanda were 95% in 1900, 97% in 1960 and 99% in 2000, which are small and with no dams.
- 1_Lephalala, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1, and 14_Mutale2 were 90% in 1900, 93% in 1960 and 96% in 2000 where the rivers are larger.
- 7_Sand was 85% in 1900, 90% in 1960 and 95% in 2000.
- 8_Nzhelele and 9_Ṅwaneḍi were 80% in 1900, 87% in 1960 and 95% in 2000 as these are located downstream of large dams equipped with bottom outlets releasing water at an almost constant temperature.

4.4.4 Total inorganic nitrogen (TIN)

Excess nitrogen and phosphorus can stimulate excessive plant growth that has knock-on effects for the structure and functioning of biotic communities (Dallas and Day 2004).

Total inorganic nitrogen is relevant to all fourteen EWR sites.

The main anthropogenic drivers of the TIN status are:

- Wide-spread discharge of raw or inadequately treated municipal wastewater, rich in nitrogen and phosphorus.

- Raw sewage overflows into municipal stormwater systems due to blocked sewers. This is a common occurrence in the more disadvantaged residential areas (DWAF 2001 a&b).
- Diffuse runoff and drainage from fertilized cultivated land under both irrigated and dry-land conditions. This phenomenon has been demonstrated and quantified in numerous scientific studies (e.g. Alberts and Spomer 1985; Cullis, Görgens and Rossouw 2005; Van der Laan et al. 2012; Lorentz 2012).

Assuming that the current TIN state was 100% in 2022, then (**Table 4.56**):

- 2_Rietfontein, 6_Kolope, and 10_Latonyanda were 95% at 1900, 97% at 1960 and 99% at 2000 because these PES (2022) conditions were close to natural.
- 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 9_Ṅwaneḍi, 13_Mutale1 and 14_Mutale2 were 90% at 1900, 93% at 1960 and 96% at 2000, where more land-use changes were upstream.
- 3_Olifantspruit, 7_Sand, and 11_Mutshindudi were 80% in 1900, 87% in 1960 and 95% in 2000, where more land-use changes were present near the sites.
- 1_Lephalala, and 12_Luvuvhu were 70% in 1900, 80% in 1960 and 90% in 2000 due to large changes in nutrient exports.

4.4.5 Orthophosphate (PO_4-P)

Orthophospates occur in solution as numerous organic and inorganic dissolved forms. High concentrations can stimulate excessive growth of aquatic plants and algae and are likely to occur where wastewater effluents or leaching or runoff of fertilizers from cultivated land take place (Dallas and Day 2004).

Orthophospate is relevant to all fourteen EWR sites.

The main anthropogenic drivers of the Orthophosphates are:

- Wide-spread discharge of raw or inadequately treated municipal wastewater, rich in nitrogen and phosphorus.
- Raw sewage overflows into municipal stormwater systems due to blocked sewers. This is a common occurrence in the more disadvantaged residential areas (DWAF 2001a&b).
- Diffuse runoff and drainage from fertilized cultivated land under both irrigated and dry-land conditions. This phenomenon has been demonstrated and quantified in numerous scientific studies (e.g. Alberts and Spomer 1985; Cullis, Görgens and Rossouw 2005; Van der Laan et al. 2012; Lorentz 2012).

Assuming that the current PO_4-P state was 100% in 2022, then (**Table 4.56**):

- 2_Rietfontein, 6_Kolope, and 10_Latonyanda were 95% at 1900, 97% at 1960 and 99% at 2000 because these PES (2022) conditions were close to natural.
- 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 9_Ṅwaneḍi, 13_Mutale1 and 14_Mutale2 were 90% at 1900, 93% at 1960 and 96% at 2000, where more land-use changes were upstream.
- 3_Olifantspruit, 7_Sand, and 11_Mutshindudi were 80% in 1900, 87% in 1960 and 95% in 2000, where more land-use changes were present near the sites.
- 1_Lephalala, and 12_Luvuvhu were 70% in 1900, 80% in 1960 and 90% in 2000 due to large changes in nutrient exports.

4.4.6 Dissolved oxygen

The maintenance of adequate dissolved oxygen (DO) concentrations is critical for the survival river organisms and is a useful measure of river health.

Dissolved oxygen is relevant to all fourteen EWR sites.

The main anthropogenic drivers of the dissolved oxygen status are:

- The discharge of wastewater high in organic content (Biological Oxygen Demand) because oxygen is used up when the organic material decomposes. An increase in the number of WWTW, effluent volumes, and non-compliant effluents would decrease DO.
- The saturation concentration for dissolved oxygen is lower at higher water temperatures. Water abstractions and lower water levels impacts on river water temperatures, and therefore dissolved oxygen saturation.
- Release of low oxygen bottom waters from dams that exhibit summer thermal and dissolved oxygen stratification. The highest impacts are normally closest to the dam wall as reaeration takes place downstream.

Assuming that the current dissolved oxygen state is 100% in 2022, then under natural conditions (*c.* 1900) DO was 95%, 97% at 1960 and 99% at 2000 at all EWR sites, except for at 8_Nzhelele, and 9_Ṅwaneḍi, downstream of two large dams where bottom water releases are made so the levels would have been 90% in 1900, 93% in 1960 and 96% in 2000.

4.4.7 Biocides

Biocides are chemical substances, mixtures, or microorganisms intended to control any pest organisms. Biocidal products are used to protect people and animals, preserve goods, stop pests like insects or rodents and control viruses, bacteria, and fungi through a chemical or biological action. Common examples are disinfectants, wood preservatives and insect repellents.

Biocides are relevant to all fourteen EWR sites.

The main anthropogenic drivers of biocides status are:

- An increase in agricultural crops where biocides are routinely used to control pests or weeds.
- The types of biocides commonly used determine the toxicity to aquatic life. For some pesticides such as endosulfan, the degradation products might be more toxic than the parent compound.
- The timing of biocide applications is important. If applied during the growing season which coincides with rainfall, the risk of washoff increases.
- The unsafe disposal of expired biocides or washing out of biocide application equipment also increases the risk of contamination.

Assuming that the current biocide state is 100% in 2022, then (**Table 4.56**):

- 6_Kolope was 100% at 1900, 1960 and 2000 as PES (2022) conditions at this site is natural.
- 1_Lephalala, 2_Rietfontein, and 10_Latonyanda were 95% at 1900, 97% at 1960 and 99% at 2000 because the PES (2022) conditions at these sites was near natural.

- 3_Olifantspruit, 11_Mutshindudi, 13_Mutale1, and 14_Mutale2 were 90% at 1900, 93% at 1960 and 96% at 2000, where there was greater changes in land-use.
- 4_Mogalakwena1, 5_Mogalakwena2, 7_Sand, 8_Nzhelele, 9_Ṅwanedi, and 12_Luvuvhu were 80% in 1900, 87% in 1960 and 95% at 2000, where further land-use changes were evident.

4.5 EcoSpecifications, TPCs and recommendations for monitoring

4.5.1 Ecospecifications and TPCs

Target values were set to meet the agreed Recommended Ecological Category specified in the **EcoCategorisation Report (Volume 1).** Please note:

- EcoSpecs and TPCs were set for parameters with data available to calculate percentiles, i.e. values not to be exceeded more than 5% of the time for EC, pH and NH_4, and 50% of the time for the nutrients Total Inorganic Nitrogen (TIN) and PO_4-P (Orthophosphate).
- Since there are no guidelines for intermediate categories (**Section 4.2.2**) these were taken as the mid-point between two bounding categories.
- The nutrient boundary values for rivers developed by Dr Jan Roos were used (DWAF 2011) (**Table 4.57**) because those specified in DWAF (2008) were based on trophic status categories for reservoirs and not for rivers.

Table 4.57: Nutrient boundary values for rivers (DWAF, 2011)

Category	PO_4-P (mg/l)	TIN (mg/l)
A	0.025	0.70
B	0.060	1.47
C	0.090	2.24
D	0.125	3.00
E/F	< 0.125	>3.00

Note: Percentiles should be calculated within the framework of the current assessment method (DWAF 2008a), i.e. using the PES monitoring point as indicated for the relevant EWR site, and the most recent three to five years of data, equivalent to a minimum of 60 data points. Data used from the DWS gauging weir must be requested from the DWS Water Management System (WMS) database.

- There were no data to calculate EcoSpecs and TPCs for Temperature, DO, Turbidity and Biocides. If and when data are available, the data record can be analysed following the example done for Temperature (Dallas & Rivers-Moore 2019, **Figure 4.21**) where deviation from reference was described for ecological category **A** to **F** as follows: **A/B** falls within the 95% band; **C/D** falls within the +1 standard deviation band; and **E/F** falls within the +2 standard deviations band.

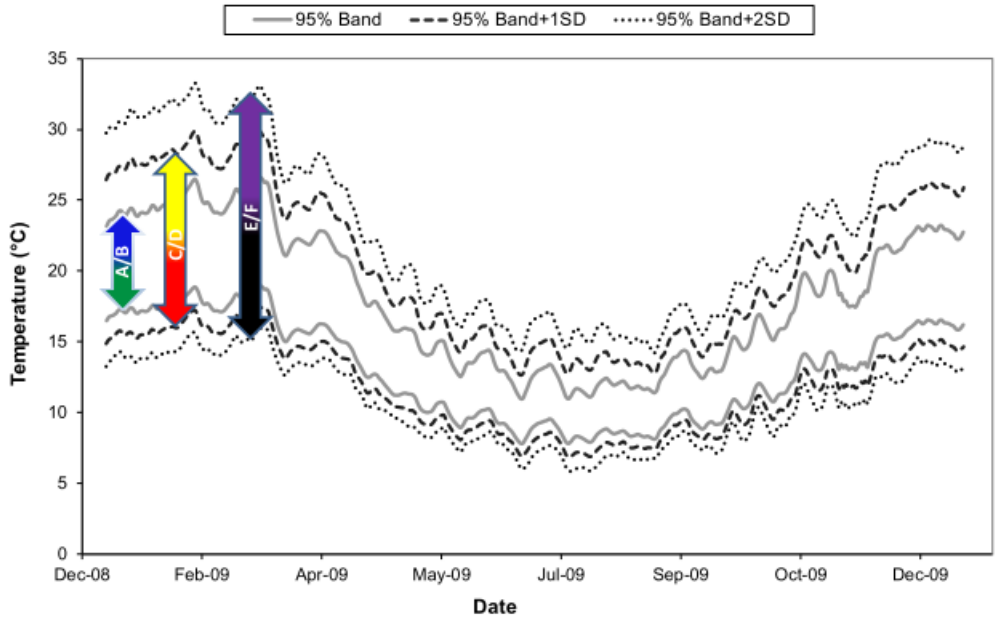


Figure 4.21: A thermograph and the reduction in ecological categories for temperature following one and two standard deviations (Dallas & Rivers-Moore, 2019)

The water quality EcoSpecs and TPCs for the fourteen EWR sites, specified to maintain them in the recommended ecological category (REC), are given in **Table 4.58** to **Table 4.71**.

Table 4.58: Water quality Ecospecs and TPCs for EWR 1_Lephalala

EWR site 1_Lephalala **REC = B/C**		
Data source A5H004Q01		
Metrics	Ecospecs	TPCs
Physical variables		
Electrical conductivity (mS/m)	< 70 mS/m (95th percentile)	95th percentile between 56 - 70 mS/m
pH	5.75 – 9.0 (5th and 95th percentiles)	The 5th percentile between 5.75-5.9, or 95th percentile between 8.8 – 9.0
Nutrients		
Total inorganic nitrogen (TIN) (mg/l)	< 1.90 mg/l (50th percentile)	50th percentile between 1.52 – 1.90 mg/l
Orthophosphate (mg/l)	< 0.075mg/l (50th percentile)	50th percentile between 0.072 – 0.075 mg/l
Toxics		
Ammonia (NH_3-N) (mg/l)	< 0.044 mg/l (50th percentile)	50th percentile between 0.035 – 0.044 mg/l

Table 4.59: Water quality Ecospecs and TPCs for EWR 2_Rietfontein

EWR site 2_Rietfontein **REC = B/C**		
Data source ZQMTOG4		
Metrics	Ecospecs	TPCs
Physical variables		
Electrical conductivity (mS/m)	< 260 mS/m (95th percentile)	95th percentile between 208 - 260 mS/m
pH	5.75 – 9.0 (5th and 95th percentiles)	The 5th percentile between 5.75-5.9, or 95th percentile between 8.8 – 9.0
Nutrients		
Total inorganic nitrogen (TIN) (mg/l)	< 1.90 mg/l (50th percentile)	50th percentile between 1.52 – 1.90 mg/l
Orthophosphate (mg/l)	< 0.075 mg/l (50th percentile)	50th percentile between 0.072 – 0.075 mg/l
Toxics		
Ammonia (NH_3-N) (mg/l)	< 0.044 mg/l (50th percentile)	50th percentile between 0.035 – 0.044 mg/l

Table 4.60: Water quality Ecospecs and TPCs for EWR 3_Olifantspruit

EWR site 3_Olifantspruit **REC = C**		
Data source A6H012Q01		
Metrics	Ecospecs	TPCs
Physical variables		
Electrical conductivity (mS/m)	< 85 mS/m (95th percentile)	95th percentile between 68 - 85 mS/m
pH	5.6 – 9.2 (5th and 95th percentiles)	The 5th percentile between 5.6-5.9, or 95th percentile between 8.8 – 9.2
Nutrients		
Total inorganic nitrogen (TIN) (mg/l)	< 2.24 mg/l (50th percentile)	50th percentile between 1.79 – 2.24 mg/l
Orthophosphate (mg/l)	< 0.09 mg/l (50th percentile)	50th percentile between 0.072 – 0.09 mg/l
Toxics		
Ammonia (NH_3-N) (mg/l)	< 0.073 mg/l (50th percentile)	50th percentile between 0.058 – 0.073 mg/l

Table 4.61: Water quality Ecospecs and TPCs for EWR 4_Mogalakwena1

EWR site 4_Mogalakwena1 **REC = C**		
Data source WMS A62_1000004273		
Metrics	Ecospecs	TPCs
Physical variables		
Electrical conductivity (mS/m)	< 85 mS/m (95th percentile)	95th percentile between 68 - 85 mS/m
pH	5.6 – 9.2 (5th and 95th percentiles)	The 5th percentile between 5.6-5.9, or 95th percentile between 8.8 – 9.2
Nutrients		
Total inorganic nitrogen (TIN) (mg/l)	< 2.24 mg/l (50th percentile)	50th percentile between 1.79 – 2.24 mg/l
Orthophosphate (mg/l)	< 0.09 mg/l (50th percentile)	50th percentile between 0.072 – 0.09 mg/l
Toxics		
Ammonia (NH_3-N) (mg/l)	< 0.073 mg/l (50th percentile)	50th percentile between 0.058 – 0.073 mg/l

Table 4.62: Water quality Ecospecs and TPCs for EWR 5_Mogalakwena2

EWR site 5_Mogalakwena2 **REC = C**		
Data source	A6R002Q01 (Glen Alpine Dam)	
Metrics	Ecospecs	TPCs
Physical variables		
Electrical conductivity (mS/m)	< 85 mS/m (95th percentile)	95th percentile between 68 - 85 mS/m
pH	5.6 – 9.2 (5th and 95th percentiles)	The 5th percentile between 5.6-5.9, or 95th percentile between 8.8 – 9.2
Nutrients		
Total inorganic nitrogen (TIN) (mg/l)	< 2.24 mg/l (50th percentile)	50th percentile between 1.79 – 2.24 mg/l
Orthophosphate (mg/l)	< 0.09 mg/l (50th percentile)	50th percentile between 0.072 – 0.09 mg/l
Toxics		
Ammonia (NH_3-N) (mg/l)	< 0.073 mg/l (50th percentile)	50th percentile between 0.058 – 0.073 mg/l

Table 4.63: Water quality Ecospecs and TPCs for EWR 6_Kolope

EWR site 6_Kolope **REC = C**		
Data source sampling point at 6_Kolope		
Metrics	Ecospecs	TPCs
Physical variables		
Electrical conductivity (mS/m)	< 85 mS/m (95th percentile)	95th percentile between 68 - 85 mS/m
pH	5.6 – 9.2 (5th and 95th percentiles)	The 5th percentile between 5.6-5.9, or 95th percentile between 8.8 – 9.2
Nutrients		
Total inorganic nitrogen (TIN) (mg/l)	< 2.24 mg/l (50th percentile)	50th percentile between 1.79 – 2.24 mg/l
Orthophosphate (mg/l)	< 0.09 mg/l (50th percentile)	50th percentile between 0.072 – 0.09 mg/l
Toxics		
Ammonia (NH_3-N) (mg/l)	< 0.073 mg/l (50th percentile)	50th percentile between 0.058 – 0.073 mg/l

Table 4.64: Water quality Ecospecs and TPCs for EWR 7_Sand

EWR site 7_Sand **REC = C**		
Data source sampling point at 7_Sand		
Metrics	Ecospecs	TPCs
Physical variables		
Electrical conductivity (mS/m)	< 85 mS/m (95th percentile)	95th percentile between 68 - 85 mS/m
pH	5.6 – 9.2 (5th and 95th percentiles)	The 5th percentile between 5.6-5.9, or 95th percentile between 8.8 – 9.2
Nutrients		
Total inorganic nitrogen (TIN) (mg/l)	< 2.24 mg/l (50th percentile)	50th percentile between 1.79 – 2.24 mg/l
Orthophosphate (mg/l)	< 0.09 mg/l (50th percentile)	50th percentile between 0.072 – 0.09 mg/l
Toxics		
Ammonia (NH_3-N) (mg/l)	< 0.073 mg/l (50th percentile)	50th percentile between 0.058 – 0.073 mg/l

Table 4.65: Water quality Ecospecs and TPCs for EWR 8_Nzhelele

EWR site 8_Nzhelele **REC = C**		
Data source WMS 100605		
Metrics	Ecospecs	TPCs
Physical variables		
Electrical conductivity (mS/m)	< 85 mS/m (95th percentile)	95th percentile between 68 - 85 mS/m
pH	5.6 – 9.2 (5th and 95th percentiles)	The 5th percentile between 5.6-5.9, or 95th percentile between 8.8 – 9.2
Nutrients		
Total inorganic nitrogen (TIN) (mg/l)	< 2.24 mg/l (50th percentile)	50th percentile between 1.79 – 2.24 mg/l
Orthophosphate (mg/l)	< 0.09 mg/l (50th percentile)	50th percentile between 0.072 – 0.09 mg/l
Toxics		
Ammonia (NH_3-N) (mg/l)	< 0.073 mg/l (50th percentile)	50th percentile between 0.058 – 0.073 mg/l

Table 4.66: Water quality Ecospecs and TPCs for EWR 9_Ṅwaneḍi

EWR site 9_Ṅwaneḍi **REC = C**		
Data source WMS 194545		
Metrics	Ecospecs	TPCs
Physical variables		
Electrical conductivity (mS/m)	< 85 mS/m (95th percentile)	95th percentile between 68 - 85 mS/m
pH	5.6 – 9.2 (5th and 95th percentiles)	The 5th percentile between 5.6-5.9, or 95th percentile between 8.8 – 9.2
Nutrients		
Total inorganic nitrogen (TIN) (mg/l)	< 2.24 mg/l (50th percentile)	50th percentile between 1.79 – 2.24 mg/l
Orthophosphate (mg/l)	< 0.09 mg/l (50th percentile)	50th percentile between 0.072 – 0.09 mg/l
Toxics		
Ammonia (NH_3-N) (mg/l)	< 0.073 mg/l (50th percentile)	50th percentile between 0.058 – 0.073 mg/l

Table 4.67: Water quality Ecospecs and TPCs for EWR 10_Latonyanda

EWR site 10_Latonyanda **REC = B/C**		
Data source A9H027		
Metrics	Ecospecs	TPCs
Physical variables		
Electrical conductivity (mS/m)	< 70 mS/m (95th percentile)	95th percentile between 56 - 70 mS/m
pH	5.75 – 9.0 (5th and 95th percentiles)	The 5th percentile between 5.75-5.9, or 95th percentile between 8.8 – 9.0
Nutrients		
Total inorganic nitrogen (TIN) (mg/l)	< 1.90 mg/l (50th percentile)	50th percentile between 1.52 – 1.90 mg/l
Orthophosphate (mg/l)	< 0.075 mg/l (50th percentile)	50th percentile between 0.072 – 0.075 mg/l
Toxics		
Ammonia (NH_3-N) (mg/l)	< 0.044 mg/l (50th percentile)	50th percentile between 0.035 – 0.044 mg/l

Table 4.68: Water quality Ecospecs and TPCs for EWR 11_Mutshindudi

EWR site 11_Mutshindudi **REC = C**		
Data source A9H025Q01		
Metrics	Ecospecs	TPCs
Physical variables		
Electrical conductivity (mS/m)	< 85 mS/m (95th percentile)	95th percentile between 68 - 85 mS/m
pH	5.6 – 9.2 (5th and 95th percentiles)	The 5th percentile between 5.6-5.9, or 95th percentile between 8.8 – 9.2
Nutrients		
Total inorganic nitrogen (TIN) (mg/l)	< 2.24 mg/l (50th percentile)	50th percentile between 1.79 – 2.24 mg/l
Orthophosphate (mg/l)	< 0.09 mg/l (50th percentile)	50th percentile between 0.072 – 0.09 mg/l
Toxics		
Ammonia (NH_3-N) (mg/l)	< 0.073 mg/l (50th percentile)	50th percentile between 0.058 – 0.073 mg/l

Table 4.69: Water quality Ecospecs and TPCs for EWR 12_Luvuhvu

EWR site 12_Luvuhvu **REC = C**		
Data source A9H012Q01		
Metrics	Ecospecs	TPCs
Physical variables		
Electrical conductivity (mS/m)	< 85 mS/m (95th percentile)	95th percentile between 68 - 85 mS/m
pH	5.6 – 9.2 (5th and 95th percentiles)	The 5th percentile between 5.6-5.9, or 95th percentile between 8.8 – 9.2
Nutrients		
Total inorganic nitrogen (TIN) (mg/l)	< 2.24 mg/l (50th percentile)	50th percentile between 1.79 – 2.24 mg/l
Orthophosphate (mg/l)	< 0.09 mg/l (50th percentile)	50th percentile between 0.072 – 0.09 mg/l
Toxics		
Ammonia (NH_3-N) (mg/l)	< 0.073 mg/l (50th percentile)	50th percentile between 0.058 – 0.073 mg/l

Table 4.70: Water quality Ecospecs and TPCs for EWR 13_Mutale1

EWR site 13_Mutale1 **REC = B/C**		
Data source WMS 188507		
Metrics	Ecospecs	TPCs
Physical variables		
Electrical conductivity (mS/m)	< 70 mS/m (95th percentile)	95th percentile between 56 - 70 mS/m
pH	5.75 – 9.0 (5th and 95th percentiles)	The 5th percentile between 5.75-5.9, or 95th percentile between 8.8 – 9.0
Nutrients		
Total inorganic nitrogen (TIN) (mg/l)	< 1.90 mg/l (50th percentile)	50th percentile between 1.52 – 1.90 mg/l
Orthophosphate (mg/l)	< 0.075 mg/l (50th percentile)	50th percentile between 0.072 – 0.075 mg/l
Toxics		
Ammonia (NH_3-N) (mg/l)	< 0.044 mg/l (50th percentile)	50th percentile between 0.035 – 0.044 mg/l

Table 4.71: Water quality Ecospecs and TPCs for EWR 14_Mutale2

EWR site 14_Mutale2 **REC = B/C**		
Data source A9H013Q01		
Metrics	Ecospecs	TPCs
Physical variables		
Electrical conductivity (mS/m)	< 70 mS/m (95th percentile)	95th percentile between 56 - 70 mS/m
pH	5.75 – 9.0 (5th and 95th percentiles)	The 5th percentile between 5.75-5.9, or 95th percentile between 8.8 – 9.0
Nutrients		
Total inorganic nitrogen (TIN) (mg/l)	< 1.90 mg/l (50th percentile)	50th percentile between 1.52 – 1.90 mg/l
Orthophosphate (mg/l)	< 0.075 mg/l (50th percentile)	50th percentile between 0.072 – 0.075 mg/l
Toxics		
Ammonia (NH_3-N) (mg/l)	< 0.044 mg/l (50th percentile)	50th percentile between 0.035 – 0.044 mg/l

4.5.2 Recommended monitoring

The following water quality monitoring is recommended for the implementation of the water quality Reserve:

Sampling network

- It is recommended that water quality sampling be restored at existing sampling sites near the EWR sites, and that new site be established at 6_Kolope, 7_Sand and 8_Nzhelele (**Table 4.72**).
    - A monitoring site was set up on the Sand River upstream of 7_Sand because there was no flow at 7_Sand.

Sampling protocols

- The standard DWS sampling protocol for inorganic chemical analysis should be followed when collecting, preserving, and transporting samples to an accredited water testing laboratory (DWAF 2004).
- The standard DWS sampling protocol for toxic substances (biocides) as described in the National Toxicity Monitoring Programme (NTMP) should be followed when collecting, preserving, and transporting samples to an accredited water testing laboratory (DWAF 2008).

In-situ measurements

- Water temperature and dissolved oxygen concentrations should be measured in the field when water samples are collected.
- Water temperature: Water temperature should be measured during sample collection, in the flowing part of the river, about 10 cm below the water surface, with a glass laboratory thermometer or a reputable water testing instrument (EC meter or Dissolved Oxygen meter).
- Dissolved Oxygen: Dissolved Oxygen should be measured during sample collection, in the flowing part of the river, with a dissolved oxygen meter that has been calibrated according to the manufacturer's specifications.

Constituents

- The water samples should be analysed at a SANAS accredited water testing laboratory for the standard macrochemical list by the DWS National Chemical Monitoring Programme. These include:
    - Ammonia as N

- Chloride (Cl-)
- Calcium (Ca)
- EC (Electrical Conductivity)
- Fluoride (F)
- Magnesium (Mg)
- Nitrate + nitrite as N
- Orthophosphate as P
- pH
- Potassium (K)
- Silicates as Si
- Sodium (Na)
- Sulphate (SO_4^{2-})
- Total Alkalinity (TAL)
- Total Dissolved Salts (TDS).

- It is further recommended that water samples also be analysed for suspended sediments (mg/l) and for turbidity (NTU) using standard methods for the testing of water and wastewater samples.
- Lastly, it is recommended that surveys for biocides be undertaken every 3-5 years using the standard DWS sampling protocol for toxic substances (biocides) described in the National Toxicity Monitoring Programme (NTMP) and testing the water for the compounds described in the NTMP document (DWAF 2008).

All monitoring data should be stored in the Department's WMS from where it can be extracted for evaluating compliance with water quality ecospecs and Resource Quality Objectives.

- The recommended monitoring frequency is given in **Table 4.72**.

Table 4.72: Frequency of monitoring water quality

EWR site	WQ sampling point	Frequency of monitoring
1_Lephalala	A5H004Q01	Collect a sample once a month for analysis of the standard DWS water quality parameters but include suspended sediments and turbidity and measure water temperature, dissolved oxygen concentrations. Undertake surveys for biocides every 3 years. [Hereafter called the recommended protocol].
2_Rietfontein	ZQMTOG4	Sample quarterly and follow recommended protocol.
3_Olifantspruit	A6H012Q01	Collect a sample once a month for analysis of the standard DWS water quality parameters but include suspended sediments and turbidity and measure water temperature, dissolved oxygen concentrations. Undertake surveys for biocides every 3 years. [Hereafter called the recommended protocol].
4_Mogalakwena1	A62_1000004273	
5_Mogalakwena2	WMS A6R002Q01	
6_Kolope	New site at 6-Kolope	Establish a new site and sample when flowing using the recommended protocol. These two sites only flow for a few days after rain so a site was set up on the Sand upstream of 7_Sand.
7_Sand	New site at 7_Sand	
8_Nzhelele	New site at WMS 100605	Establish a new site at WMS 100605 (Lon. 30.23806, Lat. -22.50278) and follow recommended sampling protocol.
9_Ṅwaneḍi	WMS 194545 & WMS 19544	Collect a sample once a month for analysis of the standard DWS water quality parameters but include suspended sediments and turbidity and measure water temperature, dissolved oxygen concentrations. Undertake surveys for biocides every 3 years. [Hereafter called the recommended protocol].
10_Latonyanda	A9H027	
11_Mutshindudi	A9H025Q01	
12_Luvuvhu	A9H012Q01	
13_Mutale1	WMS 188507	
14_Mutale2	A9H013Q01	

5 GEOMORPHOLOGY

5.1 Introduction

The main objective of the geomorphology study was to identify the relationship between geomorphological features and flow level changes, and to predict what impacts, if any, will occur with changes to the present day flow regimes.

5.1.1 Assumptions and limitations

The Geozones in the PES-EIS dataset were used to determine the reach gradient and associated character that formed the basis for the reference description.

The site assessments were done in ~2 hours due to logistical constraints during low flow conditions.

The resolution of the historical images was not suitable to identify in-channel changes to the smaller rivers over time, resulting in a lower confidence reference description.

5.2 EWR sites with a focus on geomorphology

5.2.1 Catchment description

There are several different geomorphic landscapes in the Limpopo basin, including plateaus, escarpments, hills, mountains, and plains (Bridges 1990). Partridge *et al.* (2010) provide a thorough description of the geomorphic regions or provinces of South Africa (**Figure 5.1**). The basic characteristics of the various geomorphic provinces, including relief, geomorphic features, river gradient, valley breadth, underlying geology and potential for storing sediment are summarized in **Table 5.1**.

As the geomorphological provinces explain the broad river landscape setting and not the river character, the South African river geomorphological classification scheme that is based on river gradient, explains the valley context and river characteristics (**Figure 5.2**) in more detail (Rowntree et al. 2000). Rowntree et al. (2000) provide the following descriptions of the zonal classifications:

- Transitional zone – ‘moderately steep river dominated by bedrock or boulder bed. Reach types include plain-bed, pool-rapid or pool-riffle. Confined or semi-confined valley floor with limited flood plain development’;
- Upper foothill zone – ‘moderately steep, cobble-bed or mixed bedrock and cobble-bed channel, with plain-bed, pool-riffle or pool-rapid reach types. Lengths of pools and riffles/rapids similar. Narrow flood plain of sand, gravel or cobble often present’;
- Lower foothill zone – ‘lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, may be locally bedrock controlled. Reach types typically include pool-riffle or pool-rapid, sand bars common in pools. Pools of a significantly greater extent than rapids or riffles. Flood plain often present’.
- Lowland river zone – ‘low gradient alluvial fine bed channel, typically regime reach type. May be confined, but fully developed meandering pattern within a distinct flood plain develops in unconfined reaches where there is an increased silt content in bed or banks’.

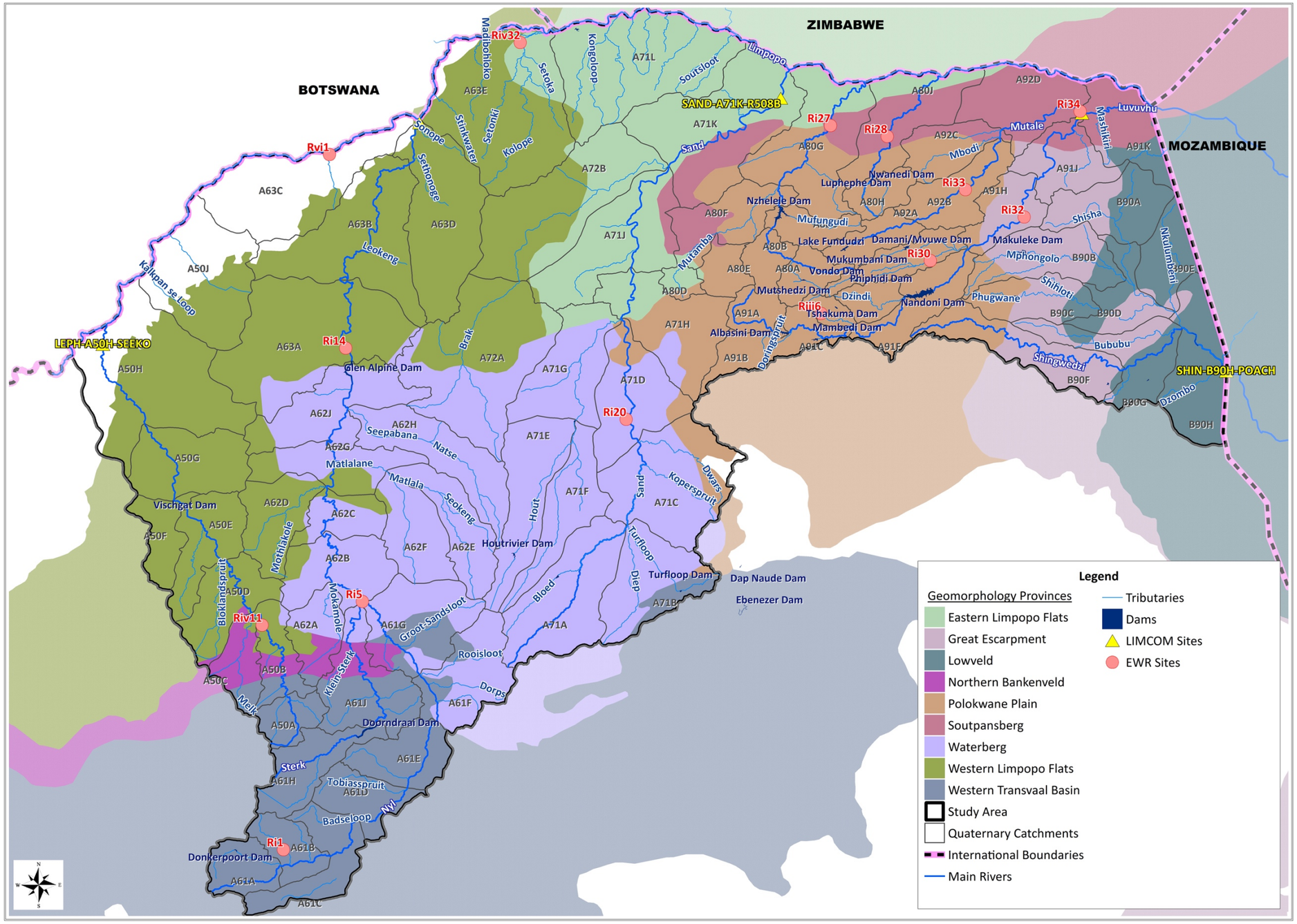


Figure 5.1: Geomorphic provinces of South Africa (Partridge et al. 2010)

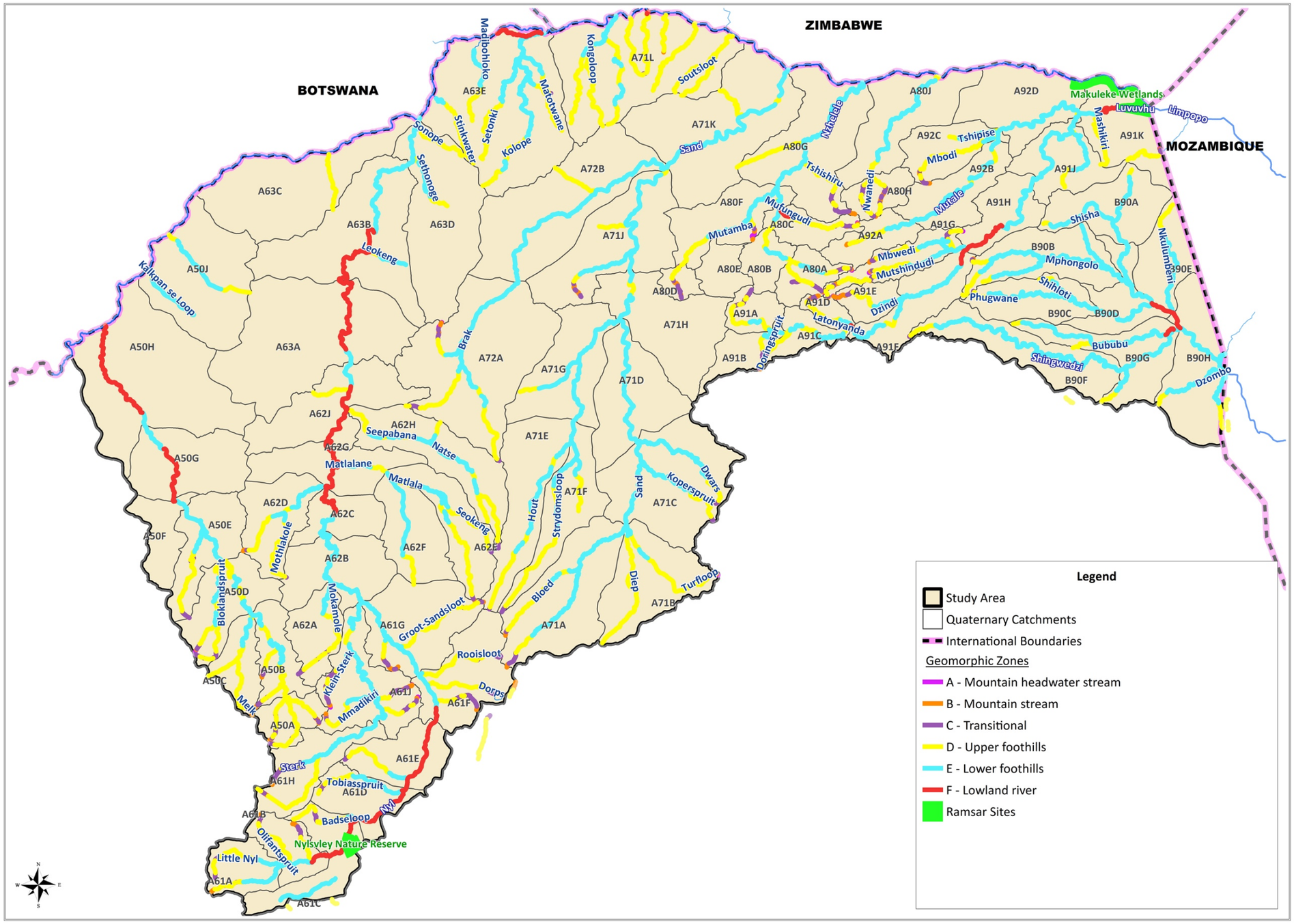


Figure 5.2: Geomorphic Zones of the Limpopo River and its tributaries (geomorphic zone data from the NBA 2018)

Table 5.1: Summary of Geomorphic Provinces for South Africa (Partridge et al. 2010)

Geomorphic Province	Description	Geology	Sediment storage
Great Escarpment	This escarpment forms a large step (300 to 2000 m vertically) between the inland plateau and the lowveld. Steep topography, steep river profiles, incised narrow valleys, mostly on bedrock with waterfalls.	Granite-gneisses and sedimentary strata of the Transvaal Supergroup	Very low
Limpopo Flats (eastern and western)	Fault controlled trough with inselberg studded plain with gentle slope. Meandering channels with broad low gradient valley. Local steepening on harder rock types of the Limpopo Belt.	Granites, gneisses, Limpopo Belt	High
Lowveld	Excavated by erosion, low undulating plains with localised koppies. Narrow to wide valley with steep to moderate river slope.	Granitic rocks	Moderate
Northern Bankenveld	Parallel quartzite ridges (e.g. Magaliesberg, Daspoort and Timeball Hill) and shale-filled valleys, trellis drainage pattern. Valleys are wide with flat river slope.	Quartzite ridges and shale in valleys	Medium to high
Polokwane Plain	Broad open valleys interspaced with numerous rocky koppies.	Granite-gneiss with schist pods	Moderate to low
Soutpansberg	Mountain range with tilting ridges and larger rivers crossing the mountain perpendicularly leading to narrow gorges, often steep flat floored valleys following fault lines. Moderate valley width and steep stepped profiles.	Soutpansberg Group quartzites, lava and shale	Low
Transvaal basin	Considerable topographical diversity with a ridge encircling a relatively flat landscape with some steep hills; gentle to medium river profiles in broad valleys.	Bushveld Complex (mainly norite, granite and felsite)	Moderate to high
Waterberg	Plateau remnants (pre-rifting residuals) separated by deeply incised, structurally-controlled valleys. Rivers range from narrow stepped deeply incised to wide gentle sandy valleys.	Waterberg sandstones, conglomerates and shales	Moderate to low

5.2.2 Data collection and analysis

The geomorphology for each site was described in terms of valley setting, river planform, morphological features, sediment composition of the various morphological features and pressures at the catchment, reach and site level. Satellite images (Google and Bing), historic airphotos (CDNGI Geospatial Portal (cdngiportal.co.za)), site photos, sediment size measurements and field sketches were used as basis for the site descriptions. Sediment size measurements were done with a Eijkelkamp Sand Ruler for sand and silt and measuring the b-axis for 100 randomly selected particles for gravel, cobble and boulder-sized particles (Gordon et al. 2004). Sediment size classes are listed in **Table 5.2**. Survey grade equipment was used to measure the slope of the channel and the cross sections of the rivers. This made it possible to construct precise geomorphological cross-sections for each site, showing the locations of important morphological features (such as benches, banks, floodplains, etc.) and physical habitats (riffles, pools, lateral sand bars, marginal zones, etc.).This information was used to populate the GAI EcoStatus field sheets as detailed in the GAI manual by Rowntree (2013).

The low water levels and low vegetation cover in winter (August 2022) made the field observations possible as the water was relatively clear, allowed access to bed sediment and the grass cover was relatively low on the morphological features.

Table 5.2: Particle size classes for sediment descriptions (adapted from Gordon *et al*. (2004) and Rowntree (2013))

Wentworth size class	Grain diameter (mm)	Feel or analogy
Very large boulder	2048 – 4096	Compact car
Large boulder	1024 – 2048	Small trailer
Medium boulder	512 – 1024	Wheel barrow
Small boulder	256 – 512	Day pack
Large cobble	128 – 256	Soccer ball
Small cobble	64 – 128	Coffee mug
Coarse gravel	16 – 64	Cricket ball
Medium gravel	8 – 16	Golf ball
Fine gravel	2 – 8	Pea
Coarse sand	0.5 – 2	Brown sugar
Medium sand	0.125 - 0.500	White sugar
Fine sand	0.063 - 0.125	Caster sugar
Silt	0.002 - 0.063	Silky
Clay	< 0.002	Sticky

Reach impacts were based on field observations where possible while driving between sites, while satellite images were used to explore the reach further. This informed changes to land use, land cover, presence and intensity of erosional features, changes to longitudinal connectivity and signs of aggradation or degradation. At the site, any evidence of erosion, deposition, trampling and changes to morphological features and vegetation were noted. These changes to the drivers and the impacts at the site were rated on the GAI field sheets and uploaded into the GAI model.

5.2.3 Description of sites

5.2.3.1 1_Lephalala

1_Lephalala was located along a partly confined valley setting. It had a single, mixed-bed channel and relatively narrow flood features (**Figure 5.3; Figure 5.4**). It followed a pool-riffle and pool-rapid reach type with fixed boulders acting as a base-level control. The channel was straight to wandering and followed the valley alignment. At the site, cobble, gravel and sand were the main mobile sediment types along the riffle and rapids (**Table 5.3**). Medium to coarse-sized sand was deposited in the pools or between boulders where flow velocities were lower. The inset and floodbenches were composed of medium to coarse sand over a cobble and boulders base. The marginal zone had a moderately dense reed, sedge and grass cover with localised trees, often alien species.



Figure 5.3: Site images of 1_Lephalala showing a) an upstream view of the channel, b) downstream view of the channel, c) sand deposits on the floodplain and d) sand bar in the pool upstream

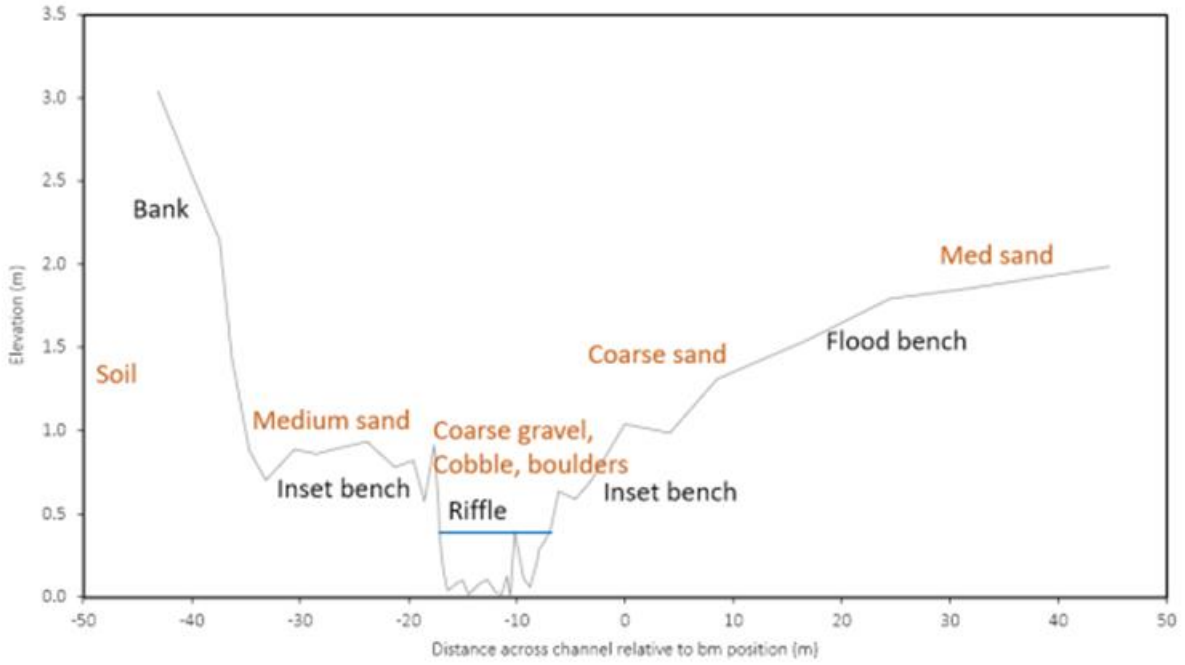


Figure 5.4: Cross-sectional view of 1_Lephalala indicating the morphological features and sediment composition

Table 5.3: Particle size for various morphological features at 1_Lephalala

Feature	Median particle size (mm) (D16 to D84)	Size class
Bed	25 (9 to 58)	Coarse gravel
Sand on bed	1 (0.5 to 3)	Coarse sand
Inset bench (right)	1.2 (0.3 to 4)	Coarse sand
Inset bench (left)	0.25 (0.125 to 0.4)	Medium sand
Floodplain	0.3 (0.125 to 0.6)	Medium sand
Upper floodplain deposit	0.5 (0.25 to 1)	Coarse sand
Left bank	<0.063	Silt

The reference state of 1_Lephalala was a lower gradient mixed bed cobble and boulder channel with limited lateral migration along a confined valley setting, resulting in a straight-to-wandering channel and pool-riffle or pool-rapid reach types. Sand bars were common in pools, with pool length exceeding riffle and rapid length. A floodplain could be present with banks of a moderate gradient. The historical images suggest that the channel margin vegetation has increased with sand filling the large pool to some extent in recent years (**Figure 5.5**).



1955 (CDNGI) | 2022 (Google Earth)

Figure 5.5: Historical and aerial images of 1_Lephalala

The hillslope-channel connectivity has been increased by localised farming, grazing and roads. Longitudinal connectivity was fairly unimpacted, with some smaller farm dams along the upper reaches and tributaries. Bank erosion was enhanced where cattle access the river channel or where road

crossings alter local hydraulics. Flood flows were possibly flashier because of increased grazing pressure and catchment connectivity. The silt and sand yield was likely to be higher due to increased surface erosion associated with agriculture and grazing. Sand deposits in the pools were due to the increased sand yield and delivery from the catchment. There was localised erosion and deposition taking place at the site, indicating a reasonable balance of geomorphological processes. The PES was in a **C** category (76%) or moderately modified condition (**Table 5.4**).

Table 5.4: Results of GAI assessment for 1_Lephalala

Geomorphological Assessment Index (GAI)					
Components	Rank	Relative Weighting (%)	Rating	Weight	Weighed Score
System Connectivity	1.00	100.00	1.23	0.43	0.54
Sediment balance	2.00	70.00	1.24	0.30	0.38
Bed & bank stability	3.00	60.00	1.06	0.26	0.28
TOTALS		230.00		1.00	1.19
GAI score (%)					76.24
Ecological category					**C**

5.2.3.2 2_Rietfontein

2_Rietfontein was located along a confined valley setting just upstream of the confluence with the Limpopo River. It had a locally steepened, single, deeply incised, mixed-bed channel with narrow flood features and no floodplain (**Figure 5.6; Figure 5.7**). It followed a plain-bed, pool-riffle or pool-rapid reach type with bedrock acting as a base-level control. The channel was straight to wandering and followed the valley alignment. At the site, fine gravel and sand were the main mobile sediment types along the bed. Minimal fine sand and silt were deposited in the pools where flow velocities were lower (**Table 5.5**). The inset and floodbenches were composed of medium to coarse sand. The inset and floodbenches had a grass and sedge cover, with trees lining the lower hillslopes.

The reference condition of 2_Rietfontein was a moderate gradient mixed bed channel with limited lateral migration along a partly confined valley setting, with a straight to wandering channel and plain-bed, pool-riffle and pool-rapid reach types. Gravel and sand were the main sediment types with a flat sand bed along lower gradient reaches and steeper bedrock rapids along steeper reaches. A narrow floodplain was present, composed of sand, gravel or cobble, with banks of a moderate gradient with inset benches present. The historical aerial images suggest that the channel morphology has been relatively stable over the past ~70 years (**Figure 5.8**).



Figure 5.6: Site images of 2_Rietfontein showing a) a downstream view of the channel, b) the floodbench and hillslope, c) an upstream view and d) the dominant bed material

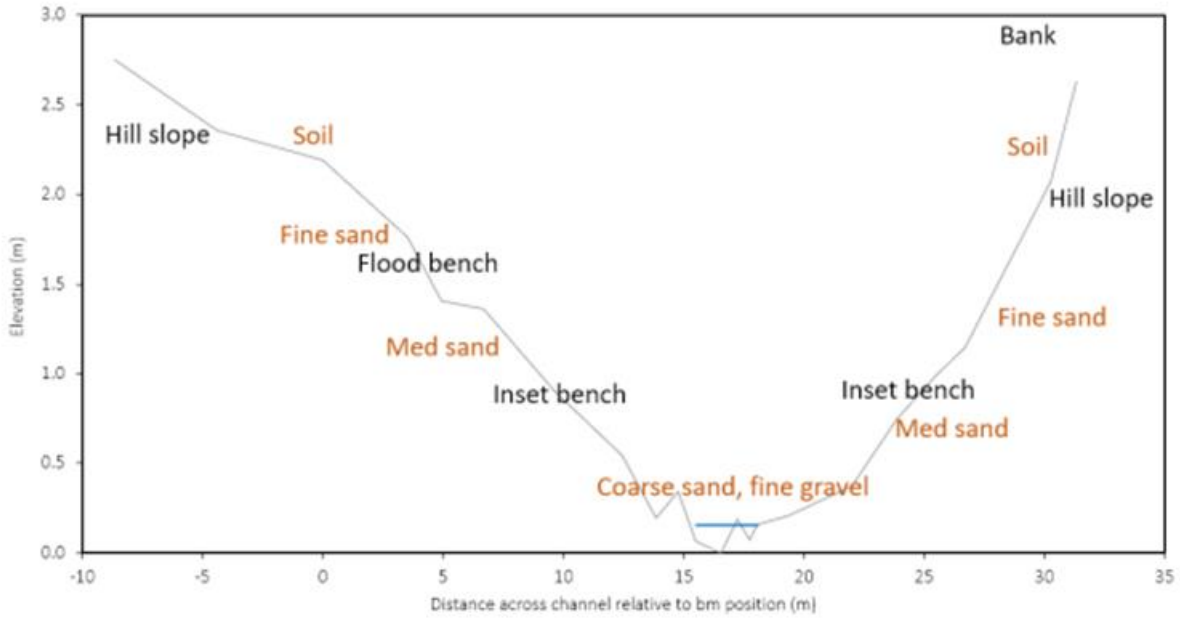
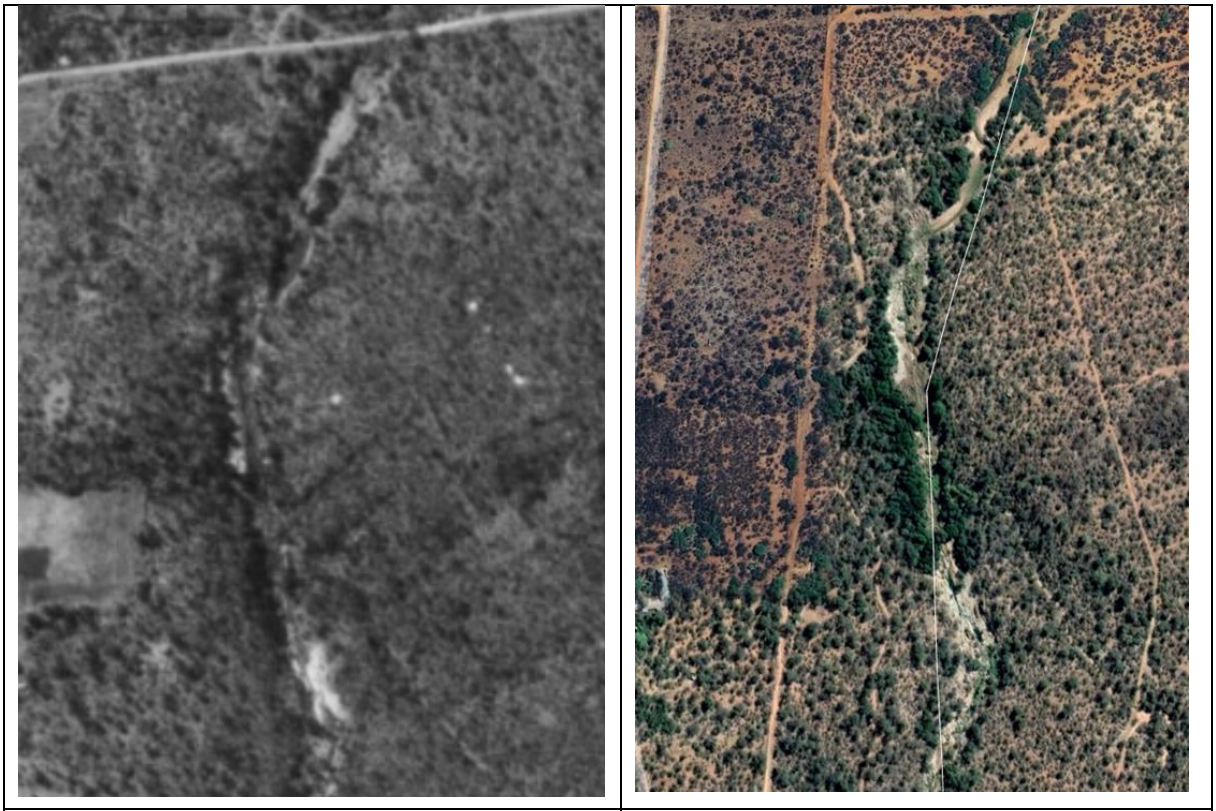


Figure 5.7: Cross-section of 2_Rietfontein showing morphological features and sediment types

Table 5.5: Particle size for various morphological features at 2_Rietfontein

Feature	Median particle size (mm) (D16, D84)	Size class
Bed (lateral bar right)	1 (0.5 to 2)	Coarse sand
Bed (lateral bar left)	4 (0.25 to 8)	Fine gravel
Inset bench	0.5 (0.2 to 0.7)	Coarse sand
Floodbench (left)	0.4 (0.25 to 1)	Medium sand
Floodbench (right)	0.3 (0.25 to 1)	Medium sand
Sand deposit up on the right bank	0.2 (0.063 to 0.4)	Medium sand



1955 (CDNGI) | 2022 (Google Earth)

Figure 5.8: Historical and aerial images of 2_Rietfontein

The hillslope-channel connectivity in the catchment has been increased by localised farming, areas with bare soil, roads and widespread grazing. Longitudinal connectivity was moderately impacted by the farm dams along the mainstem. Flood flows were possibly reduced as a result of the upstream farm dams, leading to reduced flood flows and channel narrowing. The silt and sand yield was likely to be higher due to increased surface erosion associated with agriculture, bare areas and grazing, but the coarser component of the sediment was trapped by the mainstem dams. Sand and silt deposits in the pools were due to the increased sand yield from the localised catchment. There was localised erosion and deposition taking place at the site, indicating a reasonable balance of geomorphological processes. The PES was in a **C** category (76%) or moderately modified condition (**Table 5.6**).

Table 5.6: Results of the GAI assessment for 2_Rietfontein

Geomorphological Assessment Index (GAI)					
Components	Rank	Relative Weighting (%)	Rating	Weight	Weighed Score
System Connectivity	1.00	100.00	1.37	0.43	0.60
Sediment balance	2.00	70.00	0.88	0.30	0.27
Bed & bank stability	3.00	60.00	1.22	0.26	0.32
GAI score (%)					76.39
Ecological category					**C**

5.2.3.3 3_Olifantspruit

3_Olifantspruit was located along a confined valley setting. It had a single mixed-bed channel with narrow flood features (**Figure 5.9; Figure 5.10**). It followed a pool-riffle and pool-rapid reach type with boulders and bedrock possibly acting as a base-level control. The channel was straight and followed the valley alignment. At the site, boulders, cobbles and gravels were the main substrates along the riffle with medium-sized sand along the pools. There was limited fine sediment deposition at the site due to the steep gradient. The banks were composed of fine to medium sand and silt (**Table 5.7**). Trees and reeds were present along the margins.

The reference state of 3_Olifantspruit was a moderate gradient mixed bed channel with limited lateral migration along a confined valley setting, with a straight channel and pool-riffle reach type. Boulder, cobble, gravel and sand were the main sediment types along the riffle with a sand bed along pool sections. Bedrock was locally present, forming short rapid sections and bedrock pools. Riffles and pools were of similar length. Narrow floodbenches should be present, composed of fine gravel, sand and silt, with banks of a moderate gradient and inset benches. Historical aerial images give the impression that the channel was wider and less overgrown 80 years ago (**Figure 5.11**).

The hillslope-channel connectivity had been increased by localised agriculture on the valley floor, grazing, livestock tracks and roads. Longitudinal connectivity was impacted by localised farm dams. Catchment-wide flood flows were likely increased by increases in connectivity. The silt and sand yield were likely to be higher due to increased local surface erosion associated with agriculture and grazing, but there was very little deposition at the site. There was widespread erosion along the channel margin and banks, with very little deposition at the site, indicating erosion as the dominant geomorphological process. The local crossing point for vehicles (the bridge had changed local hydraulics) and livestock, and alien vegetation along the banks all contributed to channel destabilisation. The PES was in a **C** category (76%) or moderately modified condition (**Table 5.8**).



Figure 5.9: Site images of 3_Olifantspruit showing a) a downstream view of the channel, b) an upstream view of the channel, c) bank erosion and d) the dense vegetation cover and location of the cross-section

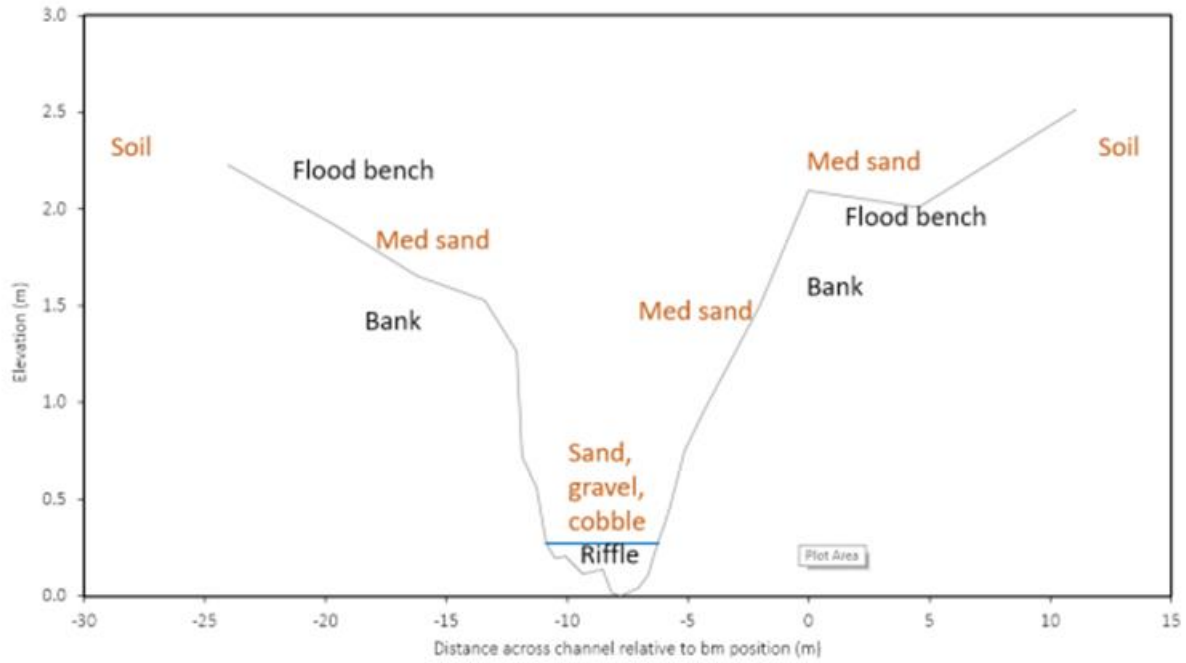
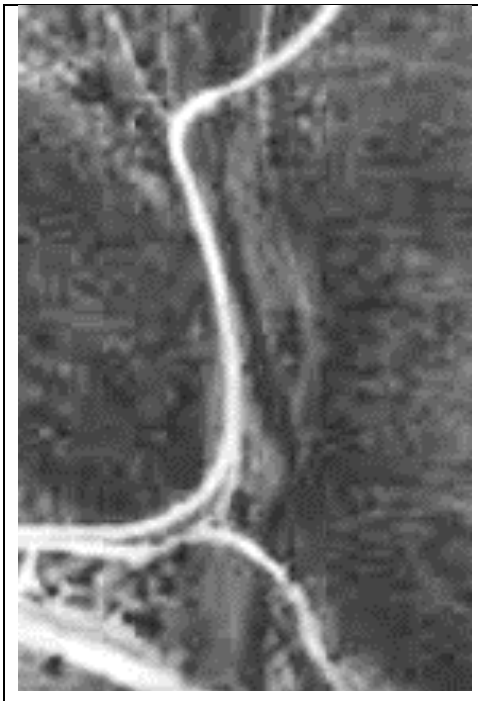


Figure 5.10: Cross-sectional view of 3_Olifantspruit indicating the main morphological features and sediment composition

Table 5.7: Particle size for various morphological features at 3_Olifantspruit

Feature	Median particle size (mm) (D16, D84)	Size class
Bed (riffle)	27 (14 to 55)	Coarse gravel
Sand on gravel bed	0.35 (0.125 to 1.5)	Medium sand
Inset bench (right)	0.35 (<0.063 to 0.7)	Medium sand
Bank (left)	0.2 (<0.063 to 0.7)	Medium sand
Floodbench deposit (left)	0.3 (0.063 to 0.5)	Medium sand
Floodbench deposit (right)	0.2 (0.063 to 0.6)	Medium sand



1939 (CDNGI)



2022 (Google Earth)

Figure 5.11: Historical aerial images of 3_Olifantspruit

Table 5.8: Results of the GAI assessment of 3_Rietfontein

Geomorphological Assessment Index (GAI)					
Components	Rank	Relative Weighting (%)	Rating	Weight	Weighed Score
System Connectivity	1.00	100.00	1.10	0.43	0.48
Sediment balance	2.00	70.00	1.18	0.30	0.36
Bed & bank stability	3.00	60.00	1.30	0.26	0.34
TOTALS		230.00		1.00	1.18
GAI score					76.47
Ecological category					**C**

5.2.3.4 4_Mogalakwena1

4_Mogalakwena1 was located along a partly confined valley setting at the confluence of two rivers. It had a single alluvial channel with a localised floodplain upstream of the confluence. It followed a pool-riffle-reach type with cobbles acting as a base-level control. The channel was straight to wandering and followed the valley alignment. At the site, cobble, gravel and sand were the main mobile sediment types along the riffle (**Figure 5.12; Figure 5.13**). Medium to coarse-sized sand was deposited in the pools or between boulders where flow velocities were lower (**Table 5.9**). The inset and floodbenches were composed of fine gravel and medium to coarse sand. The marginal zone had a moderately dense reed and grass cover with localised trees on the flood features.

The reference state of 4_Mogalakwena1 was a lower gradient alluvial cobble and sand bed channel with limited lateral migration along a partly confined valley setting, with a straight to wandering channel and pool-riffle reach types. Sand bars were common in pools, with pool length exceeding riffle length. A floodplain was present with banks of a moderate gradient with inset benches. Based on the historical images, the planform had adjusted laterally, possibly after river training took place earlier in the century (**Figure 5.14**). The channel seems larger in the recent photo, possibly due to increased flood runoff.



Figure 5.12: Site images of 4_Mogalakwena1 showing a) a downstream view of the channel, b) an upstream view of the channel, c) an oblique view in a downstream direction and d) the cobble and sandy nature of the floodbench

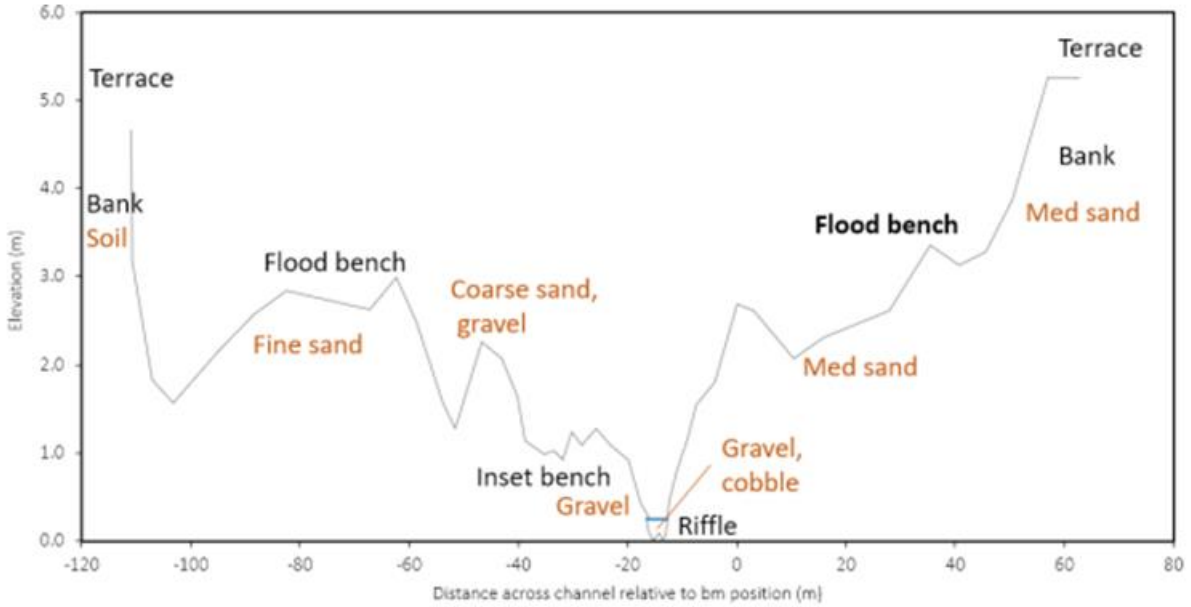


Figure 5.13: Cross-sectional view of 4_Mogalakwena1 showing the morphology and sediment composition

Table 5.9: Particle size for various morphological features at 4_Mogalakwena1

Feature	Median particle size (mm) (D16, D84)	Size class
Bed	30 (16 to 65)	Coarse gravel
Gravel bar (left)	4 (1 to 8)	Fine gravel
Inset bench (left)	0.8 (0.35 to 2)	Coarse sand
Inset bench (right)	0.3 (0.15 to 0.6)	Medium sand
Floodbench (right)	0.25 (0.09 to 1)	Medium sand
Floodbench dep (left)	0.3 (0.09 to 0.7)	Medium sand
Bank (left)	0.2 (0.09 to 0.6)	Medium sand
Bank (right)	0.15 (0.063 to 0.25)	Medium sand

The catchment hillslope-channel connectivity has been increased by localised farming, settlements with bare soil and roads and widespread grazing. Longitudinal connectivity was reduced by some smaller mainstem dams and smaller farm dams along the upper reaches and tributaries. Bank erosion was enhanced where cattle access the river channel or where road crossings alter local hydraulics. Flood flows were possibly flashier because of increased hillslope-channel connectivity. The silt and sand yield was likely to be higher due to increased surface erosion associated with agriculture, bare urban areas and grazing. Sand and silt deposits in the pools were due to the increased fine sediment yield from the catchment. There was localised erosion and deposition taking place at the site, indicating a reasonable balance of geomorphological processes.



1972 (CDNGI) | 2022 (Google Earth)

Figure 5.14: Historical aerial images of 4_Mogalakwena1

The PES was in a **C** category (67%) or moderately modified condition (**Table 5.10**).

Table 5.10: Results of the GAI assessment for 4_Mogalakwena1

Geomorphological Assessment Index (Gai)					
Components	Rank	Relative Weighting (%)	Rating	Weight	Weighed Score
System Connectivity	1.00	100.00	1.39	0.40	0.55
Sediment balance	2.00	80.00	1.75	0.32	0.56
Bed & bank stability	3.00	70.00	1.89	0.28	0.53
TOTALS		250.00		1.00	1.64
GAI score (%)					67.14
Ecological category					**C**

5.2.3.5 5_Mogalakwena2

5_Mogalakwena2 was located along a confined valley setting 5km downstream of the Glen Alpine Dam. It had a single, deeply incised, mixed-bed channel with narrow flood features and no floodplain (**Figure 5.15; Figure 5.16**). It followed a pool-riffle reach type with fixed boulders and bedrock acting as a base-level control. The channel was straight to wandering and followed the valley alignment. At the site, cobble, gravel and sand were the main mobile sediment types along the riffle (**Table 5.11**).



Figure 5.15: Site images of 5_Mogalakwena2 showing a) a downstream view of the channel, b) an upstream view of the channel, c) gravel and sand deposits on floodbenches and d) a diverse mix of sediment along the riffle

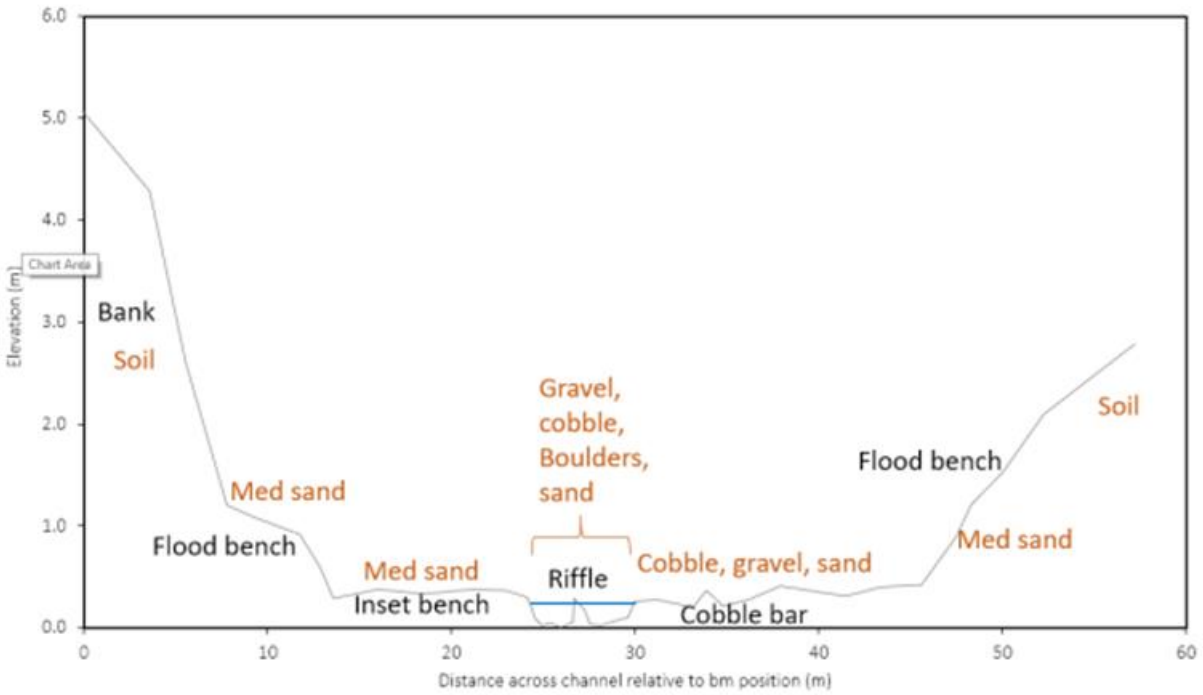


Figure 5.16: Cross-sectional view of 5_Mogalakwena2 indicating the main geomorphological features and sediment composition

Table 5.11: Particle size for various morphological features at 5_Mogalakwena2

Feature	Median particle size (mm) (D16 to D84)	Size class
Bed	35 (17 to 55)	Medium gravel
Sand bar	1.5 (0.35 to 4)	Coarse sand
Inset bench	0.4 (0.2 to 0.6)	Medium sand
Floodbench (left)	0.2 (0.09 to 0.35)	Medium sand
Floodbench (right)	0.125 (0.08 to 0.25)	Medium sand

Fine sand and silt were deposited in the pools or between boulders where flow velocities were lower. The inset and floodbenches were composed of fine to medium sand. The marginal zone had short-grazed grass and trees along the lower banks encroaching into the channel.

The reference state of 5_Mogalakwena2 was a lower gradient alluvial boulder and cobble bed channel with limited lateral migration along a confined valley setting, with a straight to wandering channel pattern and pool-riffle reach types. Sand bars would be common in pools, with the pool length exceeding riffle length. A narrow floodplain was present with banks of a moderate gradient and inset benches. Based on the aerial images, it seemed that the channel had contracted with increased vegetation on bars (**Figure 5.17**).



1957 (CDNGI) | 2020 (Google Earth)

Figure 5.17: Historical aerial images of 5_Mogalakwena2

The hillslope-channel connectivity had been increased by localised farming, settlements with extensive areas with bare soil and roads and widespread grazing. Longitudinal connectivity was heavily reduced by the Glen Alpine Dam 5km upstream. Bank erosion was enhanced where cattle accessed the river channel or where road crossings altered local hydraulics. Flood flows were likely reduced as a result of the upstream reservoir, leading to reduced flood flows and channel narrowing. The deeply incised

channel resulted in limited lateral connectivity and the armoured bed increased vertical connectivity of water movement. The silt and sand yield was likely to be higher due to increased surface erosion associated with agriculture, bare urban areas and grazing. Sand and silt deposits in the pools were due to the increased sand yield from the local catchment. There was localised erosion and deposition taking place at the site, indicating a reasonable balance of geomorphological processes despite the proximity to the upstream dam. The PES was in a **D** category (55%) or largely modified condition (**Table 5.12**).

Table 5.12: Results of the GAI assessment for 5_Mogalakwena2

Geomorphological Assessment Index (Gai)					
Components	Rank	Relative Weighting (%)	Rating	Weight	Weighed Score
System Connectivity	1.00	100.00	2.80	0.43	1.22
Sediment balance	2.00	70.00	1.71	0.30	0.52
Bed & bank stability	3.00	60.00	1.89	0.26	0.49
TOTALS		230.00		1.00	2.23
GAI score (%)					55.37
Ecological category					**D**

5.2.3.6 6_Kolope

6_Kolope was located along a partly confined valley setting just upstream of the confluence with the Limpopo River. It had a locally steepened, single, deeply incised, mixed-bed channel with narrow flood features and a terrace due to the deeply incised channel (**Figure 5.18; Figure 5.19**). It followed a plain-bed and pool-riffle reach type with bedrock possibly acting as a base-level control. The channel was straight to wandering and followed the valley alignment. At the site, fine to medium-sized sand was the main sediment type along the bed **Table 5.13**.

The inset and floodbenches were composed of silt, fine sand and medium sand. The inset and floodbenches had sparse grass cover, with trees along the banks and terrace.

The reference state of 6_Kolope was a low gradient mixed bed channel with limited lateral migration along a partly confined valley setting, with a straight to wandering channel and plain-bed and pool-riffle reach types. Gravel and sand were the main bed sediment types with a flat sand bed along lower gradient reaches. A narrow floodplain was present, composed of sand and silt, with banks of a moderate gradient with inset benches present. Under natural conditions, the system could have been less incised, but the drivers of the incision were not clear. From the historical aerial images, it can be seen that the Kolope system had incised with widespread gully erosion propagating upstream into the pan (**Figure 5.20**).



Figure 5.18: Site images of 6_Kolope showing a) a downstream view of the channel, b) an upstream view of the channel, c) steep trampled banks with limited vegetation cover and d) fine sediment (silt and clay) deposits indicating high suspended sediment concentrations during floods

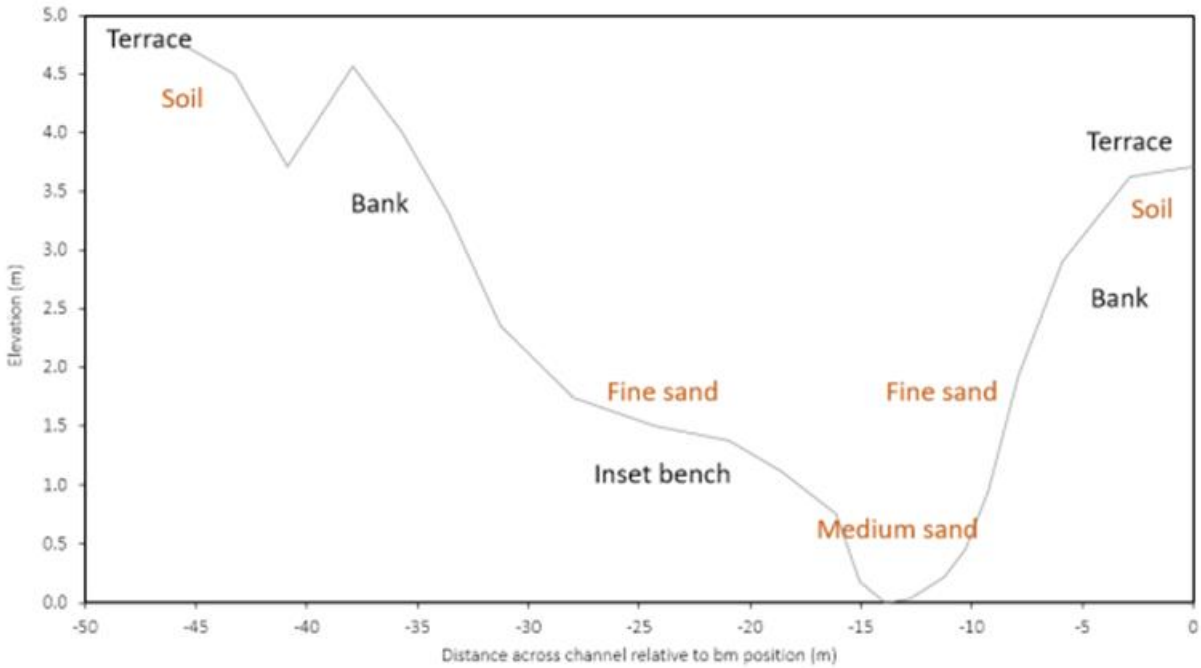
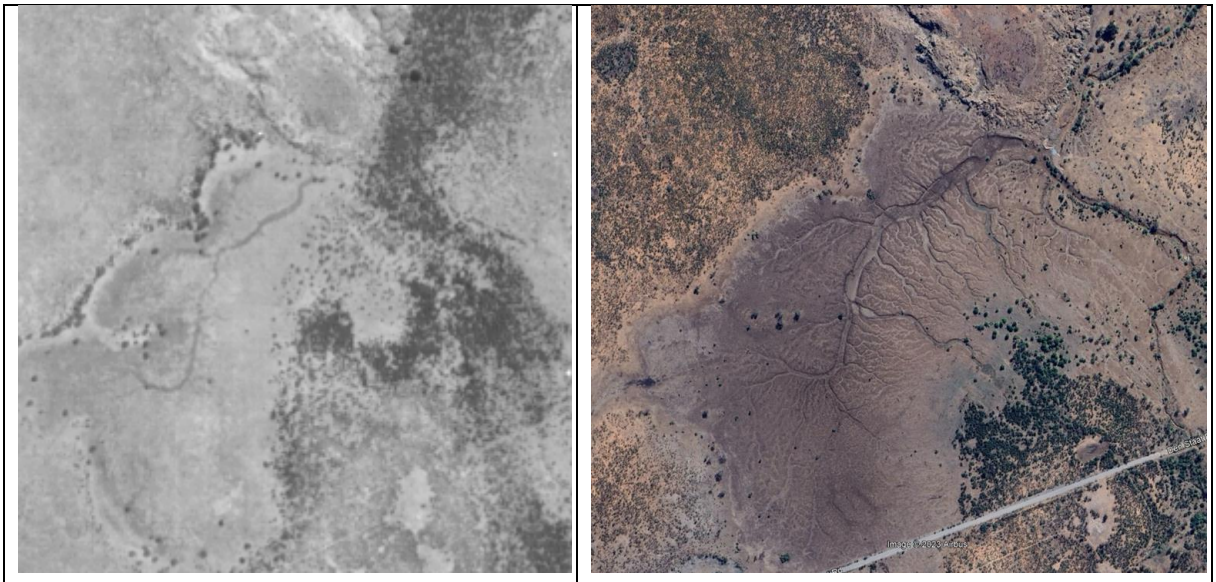


Figure 5.19: Cross-sectional view of 6_Kolope channel showing the sediment composition and morphological features

Table 5.13: Particle size for various morphological features at 6_Kolope

Feature	Median particle size (mm) (D16 to D84)	Size class
Bed	0.2 (0.125 to 0.3)	Medium sand
Inset bench (right)	0.2 (0.1 to 0.35)	Medium sand
Floodbench (left)	0.35 (0.125 to 0.5)	Medium sand
Lee deposit on floodbench	0.25 (0.125 to 0.4)	Medium sand
Left bank	0.063 (<0.063 to 0.2)	Fine Sand
Right bank	0.15 (<0.063 to 0.25)	Medium sand



1955 (CDNGI) | 2020 (Google Earth)

Figure 5.20: Historical aerial images of 6_Kolope

The hillslope-channel connectivity had been increased by localised farming and roads, large areas with bare soil and widespread grazing. Longitudinal connectivity was moderately impacted by the farm dams along the upper system and recently installed gabion weir to raise the base level of Leeu Pan. Flood flows were possibly increased as a result of catchment and Leeu Pan degradation. The silt and sand yield was likely to be higher due to increased surface erosion associated with agriculture, bare areas, overgrazing, and extensive gully development in Leeu Pan, but the coarser component of the sediment was trapped by the gabion weir construction. There was widespread erosion along the banks and localised deposition taking place at the site, indicating a degradational dominance of geomorphological processes. The PES was in a **D** category (57%) or largely modified condition (**Table 5.14**).

Table 5.14: Results of the GAI assessment for 6_Kolope

Geomorphological Assessment Index (Gai)					
Components	Rank	Relative Weighting (%)	Rating	Weight	Weighed Score
System Connectivity	1.00	100.00	2.18	0.40	0.87
Sediment balance	3.00	70.00	1.84	0.28	0.52
Bed & bank stability	2.00	80.00	2.39	0.32	0.76
TOTALS		250.00		1.00	2.15
GAI score (%)					56.96
Ecological category					**D**

5.2.3.7 7_Sand

7_Sand was located in a partly confined valley setting with a single channel and narrow flood features in a macro-channel that was incised into the surrounding low-relief landscape (**Figure 5.21; Figure 5.22**). The channel was straight to wandering and followed the valley alignment. The channel had a largely dry flat bed composed of coarse sand with localised gravel bars and bedrock outcrops forming steeper bedrock sections (**Table 5.15**). The benches were composed of medium to coarse sand and the banks were composed of finer sand and silt. It followed a glide-riffle and glide-rapid reach type with localised pools associated with rock features. The channel banks had scattered trees and dense grass vegetation with some localised trampling where livestock crossed the channel.

The reference condition of 7_Sand, based on channel gradient, should be a low-gradient, alluvial, fine-bed channel with limited lateral migration along unconfined reaches, resulting in a straight to wandering channel, with a braided pattern at very low flows. Deeper channels, pools and vegetated or bare (recently deposited) inset benches would have provided habitat along the margins. The bank would have had a moderate gradient and a narrow active floodplain, set between the higher-lying terraces. The historic aerial images suggest that infrastructure (bridge and roads) had increased with the channel remaining dominated by sand and possibly drier (**Figure 5.23**).

In the catchment, the hillslope-channel connectivity was increased by localised gullies, roads and bare areas around settlements. Longitudinal connectivity had been reduced by dams in the upper catchment and several weirs along the mainstem near the site. The fine sediment supply had been increased through widespread grazing, possibly overgrazing on communal land, trampling and roads. Sand mining was common along the channel, reducing the sand load to some extent. At the site to reach scale the channel stability had been impacted negatively by weirs, causeways, a low density of alien vegetation and trampling associated with grazing and river crossings by livestock. Flood flows were possibly flashier as a result of increased catchment denudation and increases in connectivity. The silt content was likely to be higher due to increased surface erosion associated with overgrazing and low vegetation cover in communal areas. There was localised erosion and deposition taking place, indicating a reasonable balance of geomorphological processes. The PES was in a **C** category (77%) or moderately modified condition (**Table 5.16**).



Figure 5.21: Site images of 7_Sand showing a) an upstream view of the sandy channel, b) a downstream view of the channel, c) the well-vegetated bank and c) an oblique view of the channel in an upstream direction

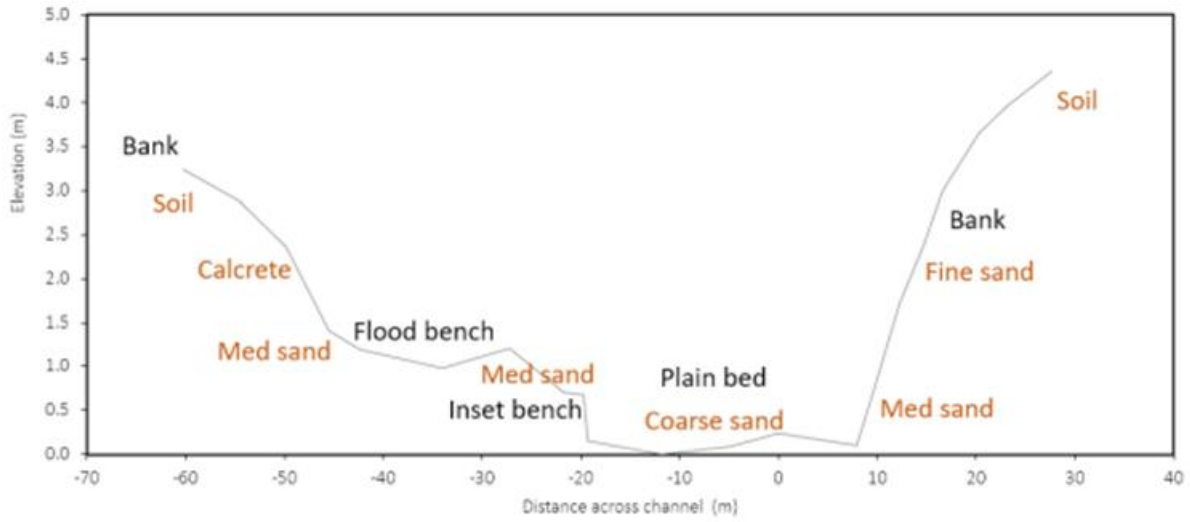


Figure 5.22: Cross-sectional view of 7_Sand channel indicating the main morphological features and sediment composition

Table 5.15: Particle size for various morphological features at 7_Sand

Feature	Median particle size (mm) (D16 to D84)	Size class
Bed	0.8 (0.125 to 2)	Coarse sand
Upper bank	0.18 (0.063 to 0.35)	Medium sand
Inset bench	0.25 (0.125 to 0.5)	Medium sand
Floodbench	0.5 (0.63 to 1)	Coarse sand
Small gravel bar	14 (8 to 22)	Medium gravel



1937 (CDNGI) | 2021 (Google Earth)

Figure 5.23: Historical aerial images of 7_Sand

Table 5.16: Results of the GAI assessment for 7_Sand

Geomorphological Assessment Index (Gai)					
Components	Rank	Relative Weighting (%)	Rating	Weight	Weighed Score
System Connectivity	1.00	100.00	1.14	0.40	0.46
Sediment balance	3.00	70.00	1.37	0.28	0.38
Bed & bank stability	2.00	80.00	1.00	0.32	0.32
TOTALS		250.00		1.00	1.16
GAI score (%)					76.80
Ecological category					**C**

5.2.3.8 8_Nzhelele

8_Nzhelele was located along a partly confined valley setting just downstream of the unconfined floodplain reach with intensive citrus production. It had a single mixed-bed channel with narrow flood features and a terrace due to the incised channel (**Figure 5.24; Figure 5.25**). It followed a pool-riffle and pool-rapid reach type with cobble and bedrock possibly acting as a base-level control. The channel was straight to wandering and followed the valley alignment. At the site, cobble and gravel were the main substrates along the riffle with medium-sized sand along the pools (Table 5.17). Large bars of cobble and gravel were present at the site. The inset and floodbenches were composed of fine gravel, coarse sand and medium sand. The banks were composed of fine sand and silt. The bars and inset benches were largely bare with localised shrubs and reeds, with tree and shrub cover along the banks.



Figure 5.24: Site images of 8_Nzhelele showing a) an oblique view of the channel in a downstream direction, b) an upstream view of the channel (note the bedrock), c) a downstream view showing steep eroding banks and d) a downstream view of the channel

The reference state of 8_Nzhelele was a low-gradient mixed bed channel with limited lateral migration along a partly confined valley setting, resulting in a straight to wandering channel and pool-rapid and pool-riffle reach types. Cobble, gravel and sand were the main sediment types along the riffle with a sand bed along lower gradient pool sections. Bedrock was locally present, forming steeper rapid sections. Sand bars were common in pools. Narrow floodbenches were often present, composed of fine gravel, sand and silt, with banks of a moderate gradient with inset benches present. The historic images indicate that the riparian tree cover had been reduced with possible increases in the extent of reeds (**Figure 5.26**).

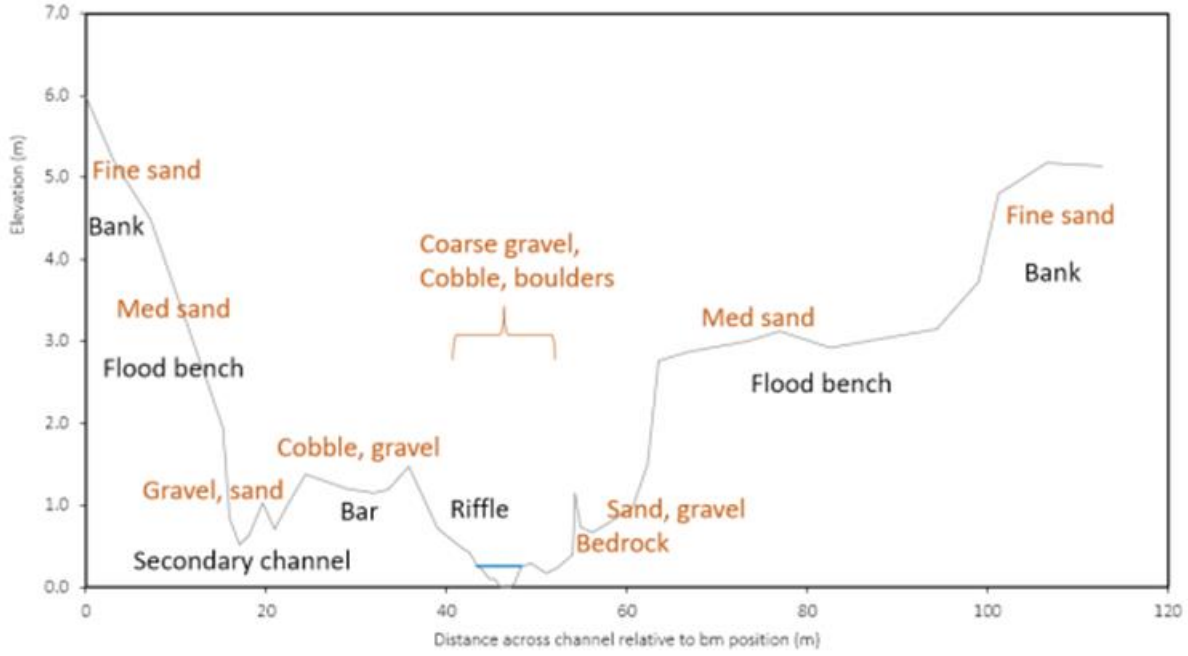


Figure 5.25: Cross-sectional view of 8_Nzhelele River indicating the main morphological features and sediment types

Table 5.17: Particle size for various morphological features at 8_Nzhelele

Feature	Median particle size (mm) (D16 to D84)	Size class
Bed	27 (11 to 82)	Coarse gravel
Floodbench	0.2 (0.063 to 0.3)	Medium sand
Sand bar (left)	0.6 (0.25 to 2)	Coarse sand
Sand bar (right)	0.4 (0.2 to 1500)	Medium sand
Left bank	0.09 (<0.063 to 0.15)	Fine sand
Right bank	0.1 (0.063 to 0.25)	Fine sand

The hillslope-channel connectivity in the catchment had been increased by localised farming and roads, large areas with bare soil and widespread grazing. Longitudinal connectivity was impacted by the Nzhelele dam 40 km upstream and increased reed growth along the lower system. Flood flows were likely reduced as a result of the reservoir. The silt and sand yield was likely to be high due to increased local surface erosion associated with agriculture, bare areas, grazing and bank erosion. There was widespread erosion along the banks and deposition was taking place at the site, indicating a possible balance of geomorphological processes despite the eroded appearance. The PES was in a **D** category (59%) or largely modified condition (**Table 5.18**).



1937 (CDNGI)



2019 (Google Earth)

Figure 5.26: Historical aerial images of 8_Nzhelele

Table 5.18: Results of the GAI assessment for 8_Nzhelele

Geomorphological Assessment Index (Gai)					
Components	Rank	Relative Weighting (%)	Rating	Weight	Weighed Score
System Connectivity	1.00	100.00	2.57	0.43	1.12
Sediment balance	2.00	70.00	1.72	0.30	0.52
Bed & bank stability	3.00	60.00	1.57	0.26	0.41
TOTALS		230.00		1.00	2.05
GAI score (%)					59.03
Ecological category					**D**

5.2.3.9 9_Ṅwaneḍi

9_Ṅwaneḍi was located along a partly confined valley setting just downstream of the confined gorge where Cross Dam was located (2 km upstream). It had a single deeply incised mixed bed channel with narrow flood features and a terrace due to the deeply incised channel (**Figure 5.27, Figure 5.28**).



Figure 5.27: Site images of 9_Ṅwaneḍi showing a) an upstream view of the incised channel, b) a downstream view of the riffle, c) exposed tree roots protecting the banks and d) sandy deposits forming the floodbenches

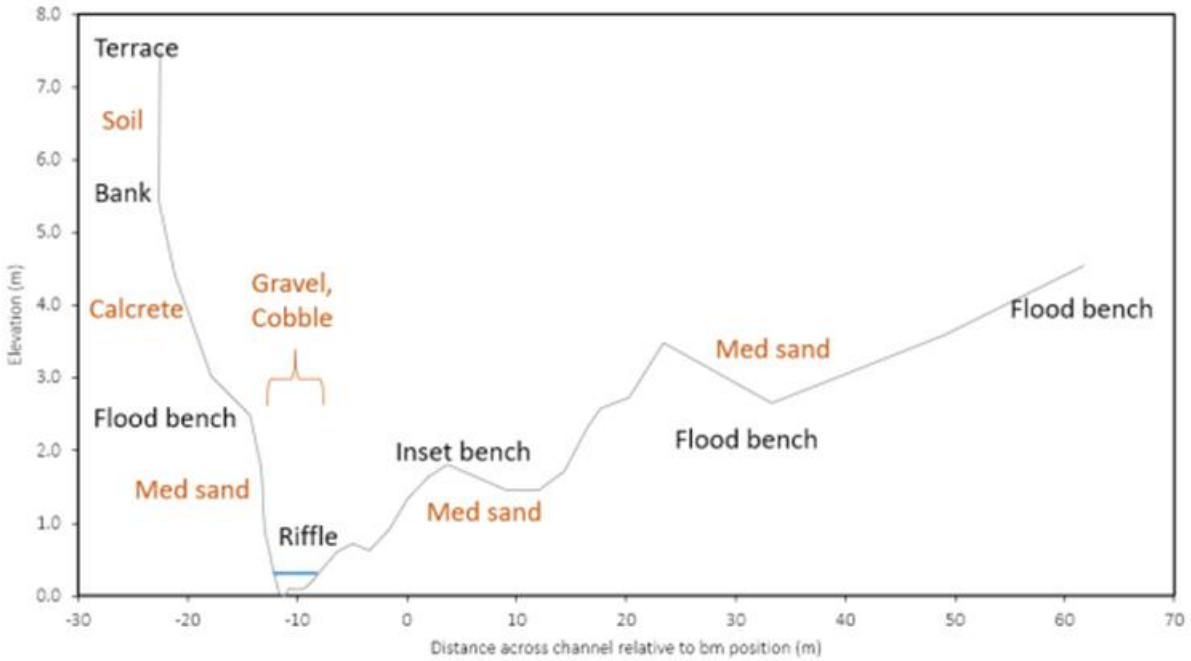


Figure 5.28: Cross-sectional view of 9_Ṅwaneḍi showing the main morphological features and sediment types

It followed a plain-bed and pool-riffle reach type with cobble and bedrock possibly acting as a base-level control. The channel was straight to wandering and followed the valley alignment. At the site, cobble and gravel were the main substrates along the riffle with medium-sized sand along the pools and plain-bed sections (**Table 5.19**). The inset and floodbenches were composed of fine gravel, fine sand and medium sand. The inset and floodbenches were largely bare, with tree and invasive shrub cover along the higher margins.

Table 5.19: Particle size for various morphological features at 9_Ṅwaneḍi

Feature	Median particle size (mm) (D16 to D84)	Size class
Bed (riffle)	32 (14 to 59)	Coarse gravel
Bank (left)	0.15 (0.063 to 0.2)	Medium sand
Sand bar on inset bench	0.3 (0.125 to 0.5)	Medium sand
Floodbench	0.25 (0.125 to 0.4)	Medium sand

The reference state of 9_Ṅwaneḍi was a low gradient mixed bed channel with limited lateral migration along a partly confined valley setting, resulting in a straight-to-wandering channel and plain-bed and pool-riffle reach types. Cobble, gravel and sand were the main sediment types along the riffle with a flat sand bed along lower gradient sections. Narrow floodbenches were often present, composed of fine gravel, sand and silt, with banks of a moderate gradient with inset benches present. Under natural conditions, the system would have been less incised. Not much can be learnt from the historical aerial images regarding the reference condition due to the dense tree canopy (**Figure 5.29**).



1937 (CDNGI) | 2022 (Google Earth)

Figure 5.29: Historical aerial images of 9_Ṅwaneḍi

The hillslope-channel connectivity had been increased by localised farming and roads, large areas with bare soil and widespread overgrazing. Longitudinal connectivity was severely impacted by the 3 large dams along the system. Flood flows were likely reduced as a result of the reservoirs. The silt and sand yield were likely high due to increased local surface erosion associated with agriculture, bare areas, and overgrazing, but the bulk of the coarser component of the sediment was trapped by the dams. There was widespread erosion along the banks (channel widening) and localised deposition taking place at the site, indicating a degradational balance of geomorphological processes. The PES was in a **D** category (57%) or largely modified condition (**Table 5.20**).

Table 5.20: Results of the GAI assessment for 9_Ṅwaneḍi

Geomorphological Assessment Index (Gai)					
Components	Rank	Relative Weighting (%)	Rating	Weight	Weighed Score
System Connectivity	1.00	100.00	2.47	0.43	1.07
Sediment balance	2.00	70.00	1.86	0.30	0.57
Bed & bank stability	3.00	60.00	1.94	0.26	0.51
TOTALS		230.00		1.00	2.15
GAI score (%)					57.08
Ecological category					**D**

5.2.3.10 10_Latonyanda

10_Latonyanda was located in a confined valley setting with a single channel and narrow flood features (**Figure 5.30, Figure 5.31**). The channel was straight to wandering and followed the valley alignment. The channel was largely a mixed bed with bedrock and fixed boulders. Cobble, gravel and sand were the main mobile sediment types along the riffle (**Table 5.21**). Sand and silt were deposited in the pools where flow velocities were lower. The benches were composed of fine sand and silt, the lower banks of gravel and cobble and the upper banks of silt and clay. It followed a pool-riffle and pool-rapid reach type with localised bedrock steps or cascades. The channel banks had a dense tree and shrub cover with some localised trampling where livestock crossed the channel.

The reference state for 10_Latonyanda was a moderate gradient mixed bed cobble and boulder channel with limited lateral migration along a confined valley setting, resulting in a straight to wandering channel and pool-riffle or pool-rapid reach types. There was limited bar formation and narrow flood features. The bank would have had a moderate gradient and comprised cobble, gravel, sand and silt. The historical aerial image showed that the tree cover had increased drastically due to afforestation (**Figure 5.32**).



Figure 5.30: Site images of 9_Latonyanda showing a) a downstream view of the channel (note the high turbidity), b) an upstream view, c) the steep nature of the banks and d) overgrown inset benches forming along pool habitat

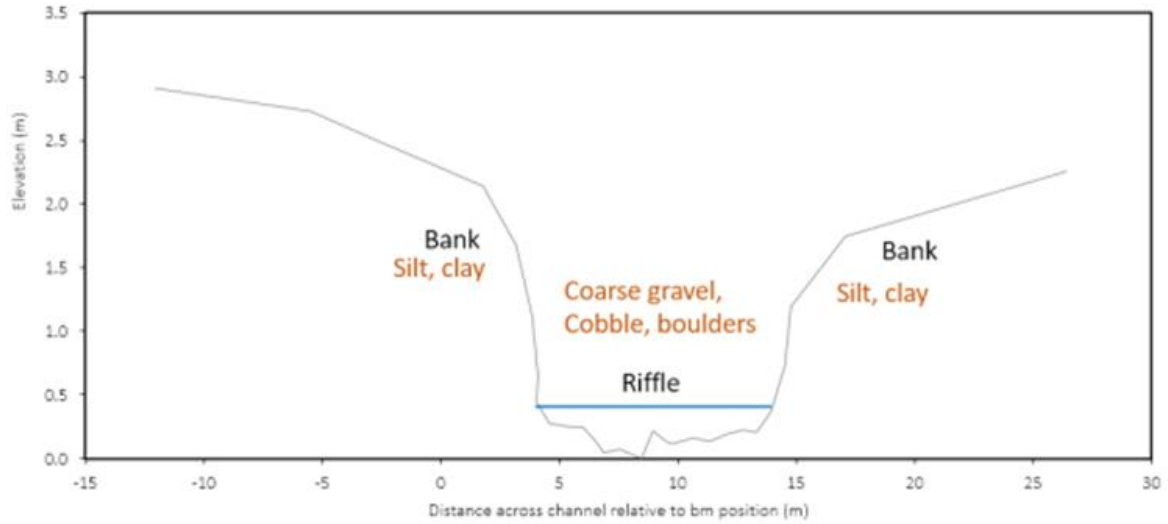


Figure 5.31: Cross-sectional view of 9_Latonyanda showing the morphology and sediment composition

Table 5.21: Particle size for various morphological features at 9_Latonyanda

Feature	Median particle size (mm) (D16, D84)	Size class
Banks	<0.063	Silt and clay
Bed	14 (7 to 56)	Medium gravel



1939 (CDNGI)



2022 (Google Earth)

Figure 5.32: Historical aerial images of 9_Latonyanda

The water had a high turbidity, indicating high erosion rates in the catchment and effective transport to the river channel. The hillslope channel connectivity had been increased by forestry activities, roads and bare areas (clear felled forestry blocks). Longitudinal connectivity had been reduced by small forestry dams in the upper catchment. Bank erosion was enhanced around bridge crossings or areas where livestock accessed the river channel. At the site to reach scale the channel stability had been impacted negatively by bridges, alien vegetation on the banks and trampling associated with grazing and river crossings by livestock. Flood flows were possibly flashier as a result of increased catchment denudation during harvesting and increases in connectivity. The silt content was likely higher due to increased surface erosion associated with forestry, clearing and grazing. There was localised erosion and deposition taking place, indicating a reasonable balance of geomorphological processes, and possibly elevated siltation rates. The PES was in a **C** category (74%) or moderately modified condition (**Table 5.22**).

Table 5.22: Results of the GAI assessment for 9_Latonyanda

Geomorphological Assessment Index (Gai)					
Components	Rank	Relative Weighting (%)	Rating	Weight	Weighed Score
System Connectivity	1.00	100.00	1.34	0.53	0.71
Sediment balance	2.00	50.00	1.70	0.26	0.45
Bed & bank stability	3.00	40.00	0.76	0.21	0.16
TOTALS		190.00		1.00	1.31
GAI score (%)					73.71
Ecological Category					**C**

5.2.3.11 11_Mutshindudi

11_Mutshindudi was located along a partly confined valley setting. It had a single mixed-bed channel with narrow flood features and a terrace due to the incised channel (**Figure 5.33; Figure 5.34**). It followed a pool-riffle and pool-rapid reach type with boulders and bedrock possibly acting as a base-level control. The channel was straight to wandering and followed the valley alignment. At the site, angular boulders, cobbles and gravels were the main substrates along the riffle with medium-sized sand along the pools and on the inset benches (**Table 5.23**). There was limited sediment deposition at the site due to the steep gradient and bedrock nature, leaving the site mainly without depositional features, but bench formation was evident up and downstream. The banks were composed of fine sand and silt (left bank) and bedrock and cobble/gravel on the right bank. Trees and reeds were present along the margins where they grew in rock fissures or coarse sediment. The bars and inset benches up and downstream of the site were lined with reeds, grasses and shrubs.

The reference state of 11_Mutshindudi was likely a low gradient mixed bed channel with limited lateral migration along a partly confined valley setting, with a straight-to-wandering channel and pool-riffle reach types. Boulder, cobble, gravel and sand were likely to be the main sediment types along the riffle with a sand bed along pool sections. Bedrock was locally present, forming short rapid sections and bedrock pools. Sand bars would have been common in pools. Narrow floodbenches would be present, composed of fine gravel, sand and silt, with banks of a moderate gradient and inset benches. The historical aerial images suggest that the current channel was in a more stable state due to increased marginal vegetation and fewer bare sand and gravel bars (**Figure 5.35**).

The hillslope-channel connectivity had been increased by widespread agriculture, overgrazing, livestock tracks, rural housing with bare areas around houses, and a moderate density of roads. Longitudinal connectivity was impacted by the Tate Vonḍo Dam (~35 km upstream). Catchment-wide flood flows were likely reduced because of the reservoir, reducing the coarser bedload delivery from the upper catchment. Flooding from the lower catchment appeared severe as there was widespread erosion at the site. The silt and sand yield was likely to be high due to increased local surface erosion associated with agriculture, bare areas and overgrazing, but there was very little deposition at the site. Localised sand mining along the channel and banks was taking place. There was widespread erosion along the channel margin and banks showed very little sediment deposition, indicating erosion was the dominant geomorphological process. Sediment deposition was evident further up and downstream; thus the erosion was likely to be localised and possibly enhanced by the steep nature of the site and the crossing point where wood harvesting, trampling and grazing were widespread. The PES was in a **C** category (65%) or moderately modified condition (**Table 5.24**).



Figure 5.33: Site images of 10_Mutshindudi showing a) an oblique channel overview in an upstream direction (note the eroded banks), b) an upstream view of the riffle, c) a view of the riffle from the right bank and d) a downstream view of the riffle

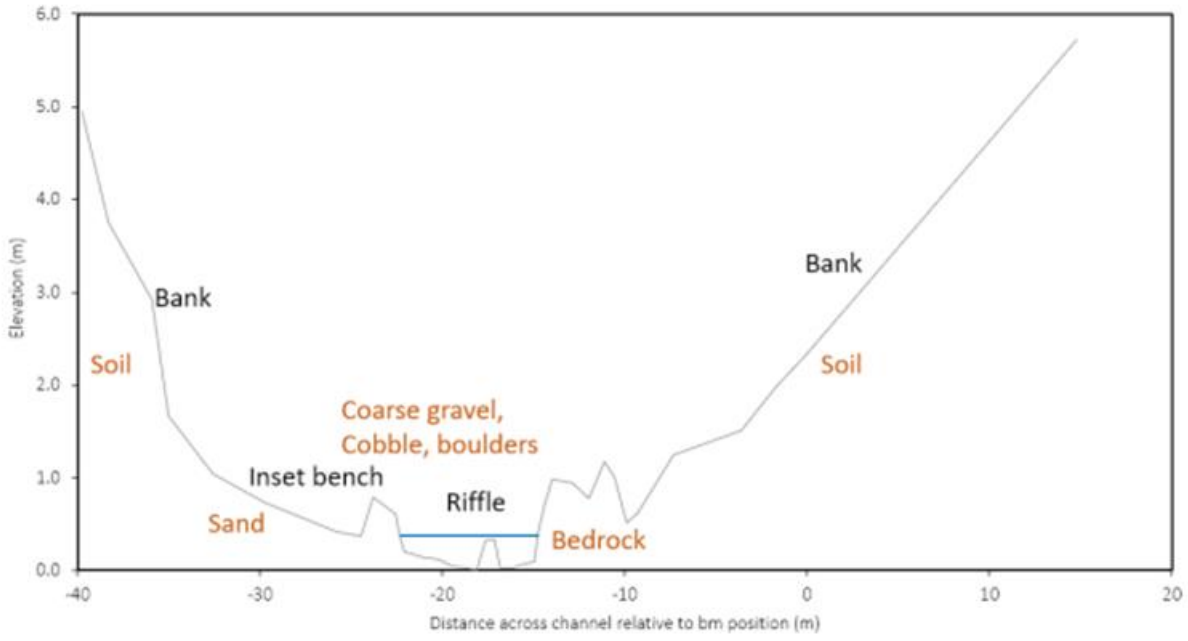


Figure 5.34: Cross-section of 11_Mutshindudi showing the main morphological features and sediment types

Table 5.23: Particle size for various morphological features at 11_Mutshindudi

Feature	Median particle size (mm) (D16 to D84)	Size class
Bed	25 (13 to 50)	Coarse gravel
Inset bench	0.35 (0.15 to 0.6)	Medium sand



1937 (CDNGI)



2021 (Google Earth)

Figure 5.35: Historical aerial images of 11_Mutshindudi

Table 5.24: Results of the GAI assessment for 11_Mutshindudi

Geomorphological Assessment Index (Gai)					
Components	Rank	Relative Weighting (%)	Rating	Weight	Weighed Score
System Connectivity	1.00	100.00	1.68	0.43	0.73
Sediment balance	2.00	70.00	1.88	0.30	0.57
Bed & bank stability	3.00	60.00	1.80	0.26	0.47
TOTALS		230.00		1.00	1.77
GAI score (%)					64.54
Ecological category					**C**

5.2.3.12 12_Luvuvhu

12_Luvuvhu was located along a partly confined valley setting. It had a single mixed-bed channel with narrow flood features and a terrace due to the incised channel (**Figure 5.36; Figure 5.37**). It followed a pool-riffle and pool-rapid reach type with boulders and bedrock possibly acting as base-level controls. The channel was straight to wandering and followed the valley alignment. At the site, boulders, cobbles and gravels were the main substrates along the riffle with medium to coarse-grained sand along the pools (**Table 5.25**). Large sand bars formed in the pools and along the benches. Sand bars along the

benches overlaid boulder and cobble substrates. The inset and floodbenches were composed of fine gravel, coarse sand and medium sand. The banks were composed of fine sand and silt. The bars and inset benches were lined with reeds, grasses and shrubs, with tree and shrub cover along the upper banks.



Figure 5.36: Site images of 12_Luvuvhu showing a) an upstream view of the channel, b) a downstream view of the channel, c) the sandy inset bench and d) the riffle with localised bedrock

The reference state of the Luvuvhu River was likely a low gradient mixed-bed channel with limited lateral migration along a partly confined valley setting, with a straight to wandering channel and pool-riffle reach types. Boulder, cobble, gravel and sand were the main sediment types along the riffle with a sand bed along pool sections. Bedrock was locally present, forming short rapid sections. Sand bars would have been common in pools. Narrow floodbenches were present, composed of fine gravel, sand and silt, with banks of a moderate gradient and inset benches. Historical aerial images suggest that sand bars, sand mining and reed extent had increased (**Figure 5.38**).

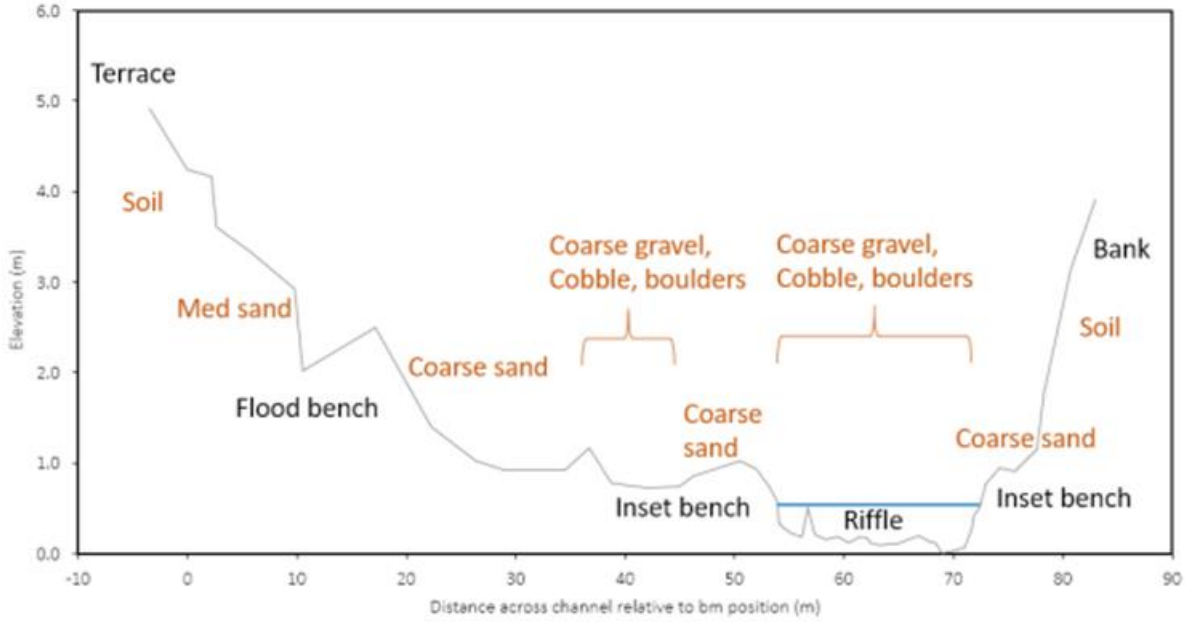


Figure 5.37: Cross-sectional view of 12_Luvuvhu showing the morphology and sediment composition

Table 5.25: Particle size for various morphological features at 12_Luvuvhu

Feature	Median particle size (mm) (D16 to D84)	Size class
Bed	35 (19 to 59)	Coarse gravel
Floodbench	0.5 (0.18 to 0.71)	Coarse sand
Inset bench	0.7 (0.35 to 1.5)	Coarse sand

The hillslope-channel connectivity had been increased by widespread agriculture, overgrazing, livestock tracks, and rural housing with bare areas around houses; a moderate density of roads. Longitudinal connectivity was impacted by the Ṋanḍoni Dam (~50 km upstream) and Albasini Dam (~100 km upstream) and the localised gauging weir. Enhanced reed growth (increased nutrients and more constant flows) along the system could have reduced longitudinal connectivity as it increases channel resistance. Flood flows were likely reduced as a result of the reservoirs, reducing the coarser bedload from the upper catchment. The silt and sand yield was likely high due to increased local surface erosion associated with agriculture, bare areas and overgrazing. Sand mining along the channel and banks disturbed sandy habitat and increased turbidity during low flow periods. There was widespread deposition along the banks and with localised erosion taking place at the site, it indicated a possible positive balance of geomorphological processes driving channel narrowing. The PES was in a **D** category (54%) or largely modified condition (**Table 5.26**).



1937 (CDNGI)



2021 (Google Earth)

Figure 5.38: Historical aerial images of 12_Luvuvhu

Table 5.26: Results of the GAI assessment for 12_Luvuvhu

Geomorphological Assessment Index (Gai)					
Components	Rank	Relative Weighting (%)	Rating	Weight	Weighed Score
System Connectivity	1.00	100.00	2.52	0.43	1.09
Sediment balance	2.00	70.00	2.24	0.30	0.68
Bed & bank stability	3.00	60.00	2.10	0.26	0.55
TOTALS		230.00		1.00	2.32
GAI score (%)					53.53
Ecological category					**D**

5.2.3.13 13_Mutale1

13_Mutale1 was located along a transition from a partly confined valley setting to a confined valley setting (**Figure 5.39; Figure 5.40**). It had a single mixed-bed channel and narrow flood features. It followed a pool-riffle and pool-rapid reach type with localised bedrock steps or cascades. The channel was straight to wandering and followed the valley alignment. The channel was largely a mixed bed with bedrock and fixed boulders along the confined downstream section and a sand bed along the less confined reaches upstream. At the site, cobble, gravel and sand were the main mobile sediment types along the riffle and rapids (**Table 5.27**). Medium-sized sand was deposited in the pools where flow velocities were lower. The inset and floodbenches were composed of medium sand. Bedrock along the valley margin was common along the confined reaches. The channel banks had a dense sedge and reed cover with localised trees.



Figure 5.39: Site images of 13_Mutale showing a) an upstream view of the site, b) a downstream view at the site, c) an upstream image showing the bedrock dominance at the site and d) a view downstream of the site showing the bedrock nature of the gorge section

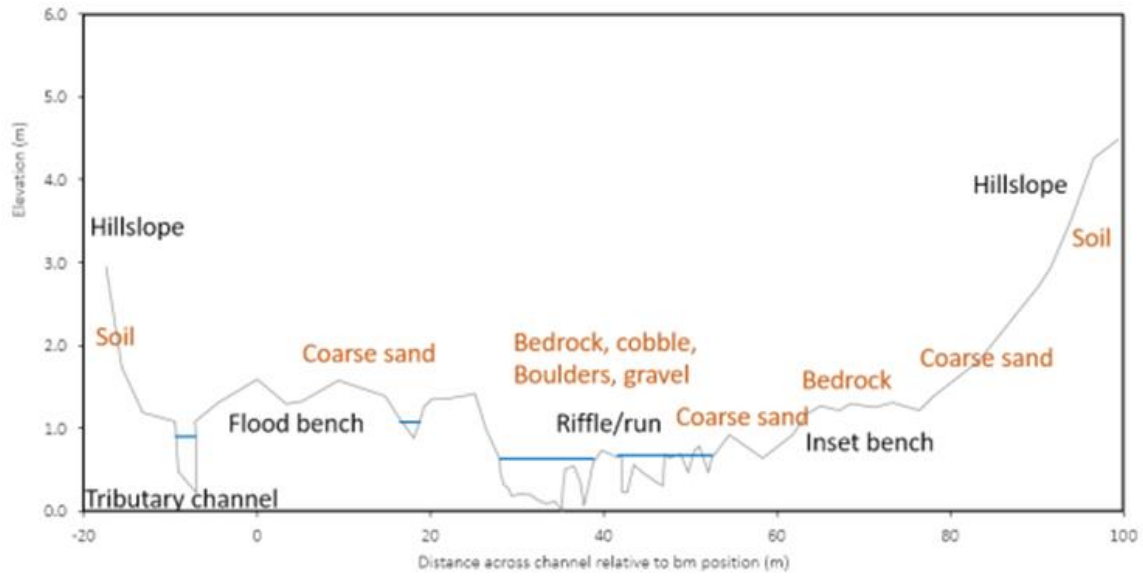


Figure 5.40: Cross-sectional view of 13_Mutale channel indicating the main morphological and sedimentological features

Table 5.27: Particle size for various morphological features at 13_Mutale

Feature	Median particle size in mm (D16 to D84)	Size class
Floodbench	0.35 (0.15 to 0.7)	Medium sand
Bed	32 (18 to 53)	Coarse gravel

The reference state of 13_Mutale1 was a low gradient mixed-bed cobble and boulder channel with limited lateral migration along a confined valley setting, with a straight to wandering channel and pool-riffle or pool-rapid reach types. Sand bars were common in pools, with pool lengths exceeding riffle and rapid lengths. The banks had a moderate gradient and comprised cobble, gravel, sand and silt. Historical aerial images show a more open and narrower channel **Figure 5.41**.



1937 (CDNGI) | 2021 (Google Earth)

Figure 5.41: Historical aerial images of 13_Mutale

The hillslope-channel connectivity had been increased by widespread subsistence farming, roads and bare areas around villages. Longitudinal connectivity was fairly unimpacted, with Lake Fundudzi being the only large natural water body along the system. Bank erosion was enhanced around bridge crossings, areas where livestock accessed the river channel or where agriculture took place on the banks. Flood flows were possibly flashier as a result of increased catchment denudation and increases in overland flow and connectivity. The silt content was likely higher due to increased surface erosion associated with agriculture and grazing. There was localised erosion and deposition taking place at the site, indicating a reasonable balance of geomorphological processes. The PES was in a **C** category (72%) or moderately modified condition **(Table 5.28)**

Table 5.28: Results of the GAI assessment for 13_Mutale1

Geomorphological Assessment Index					
Components	Rank	Relative Weighting (%)	Rating	Weight	Weighed Score
System Connectivity	1.00	100.00	1.12	0.43	0.49
Sediment balance	2.00	70.00	1.75	0.30	0.53
Bed & bank stability	3.00	60.00	1.44	0.26	0.38
TOTALS		230.00		1.00	1.40
GAI score (%)					72.07
Ecological category					**C**

5.2.3.14 14_Mutale2

14_Mutale2 was located along a transition from a confined valley setting to a partly confined valley setting. It had a single mixed bed channel, with localised anastomosing channels and narrow flood features (**Figure 5.42; Figure 5.43**). It followed a pool-riffle and pool-rapid reach type with localised bedrock steps or cascades and secondary channels. The channel was straight to wandering and followed the valley alignment. The channel was largely filled in with sand, except on steeper bedrock and fixed boulder sections. At the site, cobble, gravel and sand were the main mobile sediment types along the riffles and rapids (**Table 5.29**). Medium-sized sand was deposited in the pools where flow velocities were lower. The inset and floodbenches were composed of medium sand over cobble and boulders, with sand fining at higher elevations. Bedrock along the valley margin was common along the confined reaches. The marginal zone had a dense reed cover with localised trees.

The reference state of 14_Mutale2 was a moderate gradient mixed bed cobble and boulder channel with limited lateral migration along a confined valley setting, with a straight-to-wandering channel and pool-riffle or pool-rapid reach types. Sand bars were common in pools, with pool lengths exceeding riffle and rapid lengths. A narrow floodplain would have been present with banks of a moderate gradient comprised of cobble, gravel, sand and silt. Historical images (**Figure 5.44**) show a more vegetated channel and flood zones in 1970.

The hillslope-channel connectivity in the catchment had been increased by localised subsistence farming, grazing, roads and bare areas around villages. Longitudinal connectivity was fairly unimpacted, with a localised weir. Bank erosion was enhanced where game accessed the river channel or where road crossings or the weir influenced localised hydraulics. Flood flows were possibly flashier as a result of increased catchment denudation and increased overland flow and connectivity. The silt and sand yield was likely to be higher due to increased surface erosion associated with agriculture and grazing. Sand deposits in the pools were due to the increased sand yield from the catchment. There was localised erosion and deposition taking place at the site, indicating a reasonable balance of geomorphological processes. The PES was in a **C** category (71%) or moderately modified condition (**Table 5.30**).



Figure 5.42: Site images of 14_Mutale2 River showing a) an upstream view of the river channel, b) a downstream view of the pool habitat, c) the floodplain and d) a view of the riffle with a sand bar along the pool

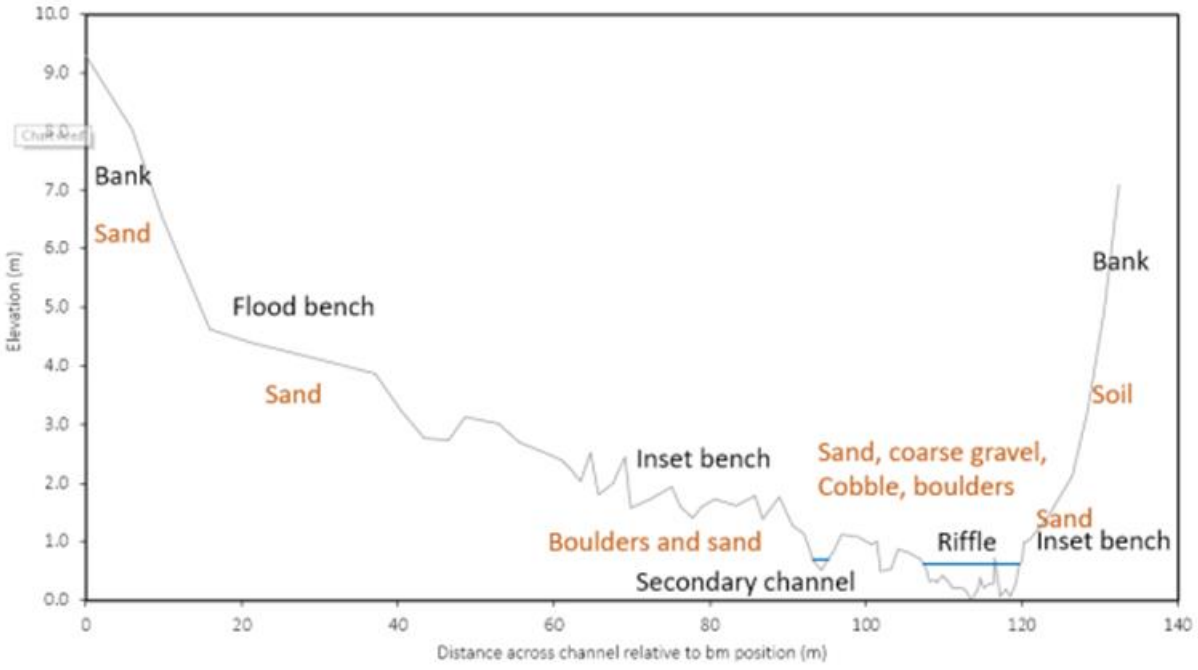
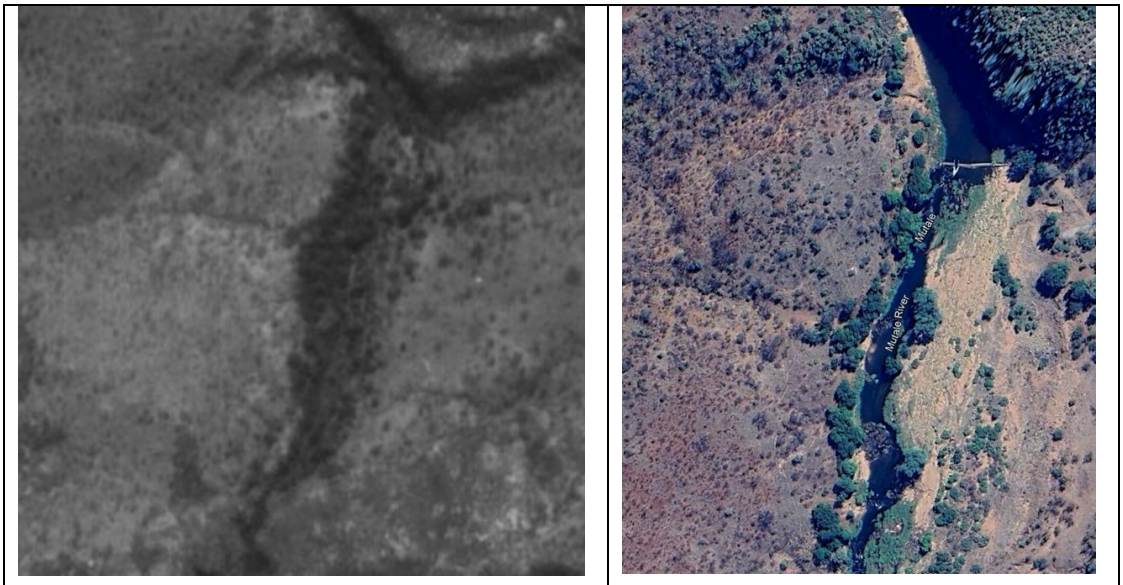


Figure 5.43: A cross-section of 14_Mutale2 showing the morphological features and dominant sediment types

Table 5.29: Particle size for various morphological features at 14_Mutale2

Feature	Median particle size (mm) (D16 to D84)	Size class
Inset bench	0.35 (0.18 to 0.7)	Medium sand
Floodbench (lower)	0.25 (0.09 to 0.4)	Medium sand
Floodbench (upper)	0.2 (0.063 to 0.5)	Medium sand
Bed (riffle)	24 (15 to 49)	Coarse gravel



1970 (CDNGI) | 2022 (Google Earth)

Figure 5.44: Historical images of 14_Mutale2

Table 5.30: Results of the GAI assessment or 14_Mutale2

Geomorphological Assessment Index (Gai)					
Components	Rank	Relative Weighting (%)	Rating	Weight	Weighed Score
System Connectivity	1.00	100.00	1.12	0.45	0.51
Sediment balance	2.00	70.00	1.70	0.32	0.54
Bed & bank stability	3.00	50.00	1.67	0.23	0.38
TOTALS		220.00		1.00	1.43
GAI score (%)					71.45
Ecological category					**C**

5.3 Geomorphology indicators

A list of geomorphology indicators and the reasons for their selection is given in **Table 5.31**.

Table 5.31: Geomorphology indicators and reasons for their selection

Indicator	Reasons for selection	EWR site													
		1_Lephalala	2_Rietfontein	3_Olifantspruit	4_Mogalakwena1	5_Mogalakwena2	6_Kolope	7_Sand	8_Nzhelele	9_Ṅwaneḍi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale1	14_Mutale2
Bed erosion	The process of lowering the active channel bed elevation in relation to flood features, possibly disconnecting the floodplain/flood features from the channel through increased channel volume. This indicator informs other geomorphic indicators.														
Bank erosion	The process of destabilisation and erosion of the banks and floodbenches resulting in a steeper less stable bank and a reduction in floodbench and floodplain width. This indicator informs other geomorphic indicators.														
Bed sediment size	The median size of sediment on the bed. Armouring will increase the size of bed sediment, while siltation will reduce the size of the bed sediment. This indicator shows trends in the median bed sediment size.														
Embeddedness	Reduction in interstitial spaces between larger clasts due to infilling with fine sediment, smothering coarse habitat associated with riffles, runs, glides and pools. This indicator shows the extent to which coarse habitats are covered with fine sediment and not available to biota.														
Pool depth	The geomorphic depth of pools in relation to riffle elevation. This indicates whether pool depth/volume changes during low flow periods.														
Backwaters and secondary channels	Slow flowing habitats along the channel margins or on the flood features. This indicates whether slow flowing habitats are filled in with sediment and not available when inundated.														
Inset bench and bars	The area/extent of fine sediment deposits along the channel margin that are inundated by small floods. These are colonised by marginal vegetation and form a habitat for a range of biota during small floods and high baseflows.														
Inundated sandy habitat	Inundated sandy habitat, on inset benches and sand bars, are important habitat for some aquatic plants and animals.														
Inundated cobble habitat	Inundated cobble habitats important habitat for some of the aquatic biota.														
Riffles	Coarse sediment habitat in fast flow. This habitat is essential for several invertebrate and fish species to complete their life cycles.														

Indicator	Reasons for selection	EWR site													
		1_Lephalala	2_Rietfontein	3_Olifantspruit	4_Mogalakwena1	5_Mogalakwena2	6_Kolope	7_Sand	8_Nzhelele	9_Ṅwaneḑi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale1	14_Mutale2
Floodbench	Infrequently inundated higher-lying fine sediment benches which form habitat for dry bank riparian plants, various biota and are a refuge for aquatic organisms during flood events.														

5.3.1 Bed erosion

Bed erosion can be described as the net export of bed material resulting in a lowering of the active channel bed elevation in relation to flood features. This can result in a change in bed sediment size, habitat diversity and disconnection of the floodplain/flood features from the channel through an increased channel volume. Bed erosion and channel incision will increase the discharge that the channel can convey, effectively reducing the frequency and time of overbank flooding, reducing habitat for instream biota during flooding and exchange of sediment, nutrients and water.

Ongoing bed erosion will result in channel incision and is often the result of reductions in sediment supply, such as downstream of a reservoir, or increases in flow, such as a river receiving additional discharge from an inter-basin transfer, increasing the discharge, shear stress and sediment transport efficiency significantly (Graf 2006; Petts and Gurnell 2005, 2005; Rowntree and Du Plessis 2003). This will result in the entrainment of the finer and coarser sediment along the bed and channel margins, resulting in the lowering of the bed and loss of bars and inset benches.

Dams interrupt the longitudinal connectivity of matter along rivers and have hydrological and geomorphic effects on downstream reaches (**Figure 5.45**). Hydrological effects can include reduced flow volumes, reduced peak flows, reduced low flows, increased low flows, changes in timing and frequency of high and low flows, changes to flow amplitude, intensity and duration (Graf 2006, Schmutz and Moog 2018).

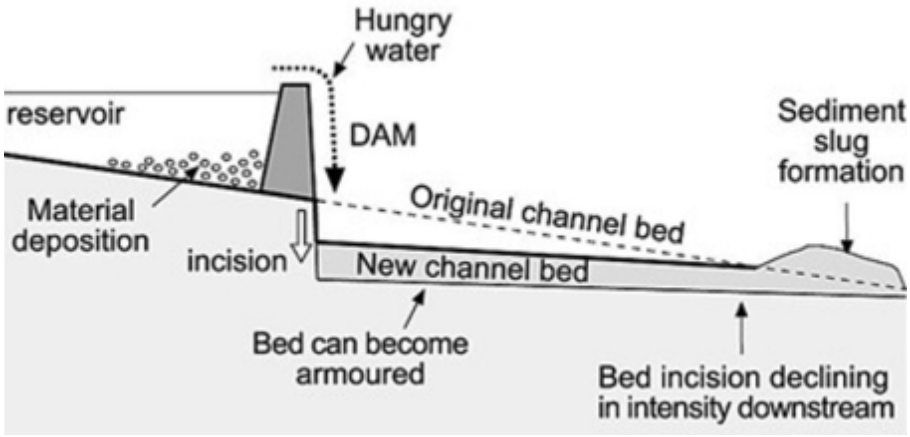


Figure 5.45: Effects of Dams on Sediment Transport and River Bed Elevation (Fryirs and Brierley 2013)

Dams act as sediment retention facilities, with larger dams being more efficient at trapping both coarse and fine sediment, whereas smaller dams are less effective in trapping fine suspended sediment due to the shorter residence time of flows (Fryirs and Brierley 2013; Schmutz and Moog 2018). This leads to a shift to fine sediment inputs only and resultant bed load starvation of downstream reaches with the system becoming supply limited. The reduction in sediment supply will result in coarsening of the bed to form a fixed armoured layer consisting of large particles (Brandt 2000). This can have a negative impact on downstream zones as nutrients are removed and turbidity is decreased by the dam (Schmutz and Moog 2018). In fine-grained channels the bed is likely to erode/incise, with subsequent lateral erosion of the banks if a stable erosional platform is reached, such as bedrock or large immobile bed material (**Figure 5.46, Case 4**). Sediment loads can be restored below confluences with large tributaries,

often leading to sediment build-up in the channel as the river flow is reduced and incompetent to transport the sediment downstream (Fryirs and Brierley 2013).

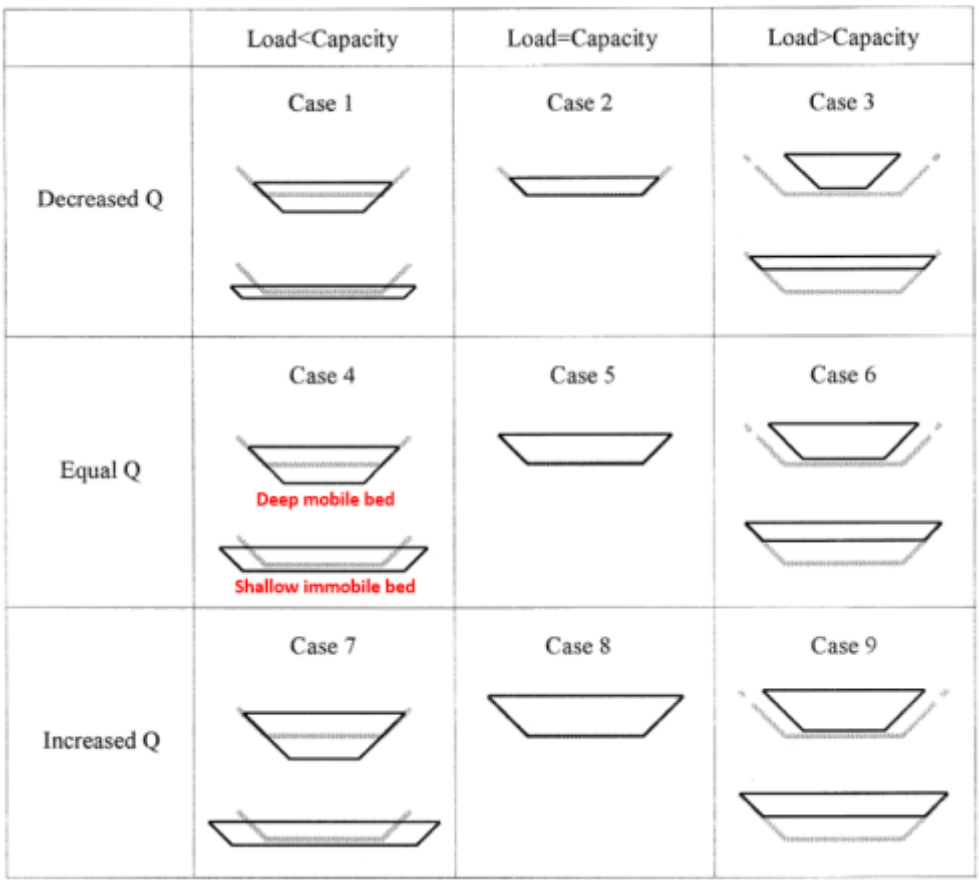


Figure 5.46: Schematic of Changes to Channel Dimensions Based on Flow (Q) and Sediment Load Alteration Downstream of Dams The grey line indicates the pre-dam channel whereas the black line indicates the possible post-dam channel dimensions (Brandt 2000)

It is expected that the channel downstream of a dam will incise and widen, leading to increased channel capacity and reduced floodplain inundation (Brandt 2000; Schmutz and Moog 2018). Associated with the channel degradation is the erosion of riffles, benches and bars, resulting in a simpler channel form (Brandt 2000). This will reduce the processes that maintain the floodplain habitat, resulting in the degradation of the floodplain habitat quality (Schmutz and Moog 2018). Reduced sediment supply to downstream reaches will lead to the degradation of floodplains, river delta systems and coastal shores (Schmutz and Moog 2018).

The linked indicators for bed erosion are given in **Table 5.32**.

Table 5.32: The reasons for, and relationship between, indicators linked to bed erosion

Linked indicator	Reasons	Relationship
T1, Wet and T2 average shear stress	Shear stress has a direct relationship to particle entrainment.	More shear stress = more bed erosion.
Sand and gravel supply	Bed erosion is balanced by sand and gravel deposition. Changes to the supply will influence the deposition of bed material.	Less sand and gravel supply = more bed erosion.
Marginal zone graminoids	Reeds and grasses along the bed will increase the channel roughness, reducing shear stress, and bind the bed material together with fine roots, giving further protection to the bed material.	More marginal zone graminoids = less bed erosion.

5.3.2 Bank erosion

Bank erosion is the process of destabilisation and erosion of the banks and floodbenches resulting in a steeper less stable bank and a reduction in floodbenches and floodplain width. Bank erosion is a natural process that rejuvenates marginal habitat by forming undercuts where biota may seek shelter or to remove bench material where vegetation is growing. Bank erosion is influenced by discharge (increased discharge results in increased shear stress driving erosional processes), sediment supply, marginal graminoids and floodbench woody vegetation. Increases in fluvial energy can lead to bed degradation and basal cleanout (removes sediment protecting the toe of the bank) resulting in bank undercutting (eroding layers of non-cohesive sediment at the base of the bank to form alcoves) (Bejarano *et al.* 2018).

Bed erosion can drive bank erosion through incision (Brandt 2000), but this was excluded to avoid double accounting as an indicator because bed erosion shares several indicators with bank erosion.

The linked indicators for bank erosion are given in **Table 5.33**.

Table 5.33: The reasons for, and relationship between, indicators linked to bank erosion

Linked indicator	Reasons	Relationship
Max 5d instantaneous discharge	Large flow events have the ability to scour sediment from the banks.	Higher discharge = more bank erosion.
T1 and T2 average discharge	Higher flows result in higher shear stress and sediment transport efficiency. This can lead to increased erosional processes along the banks.	Higher discharge = more bank erosion.
Sand and gravel supply	Bank erosion can take place when inset benches and bars are removed, exposing the bank to erosion. These features are built up when the sand and gravel supply is sufficient to counterbalance erosion.	More sand and gravel supply = less bank erosion.
Marginal zone graminoids	Reeds and grasses will protect the inset bench and lower bank, reducing the erosional processes along the bank.	More marginal zone graminoids = less bank erosion.
Floodbench woody vegetation	Deep-rooted trees along the floodbench will bind the bank material with their roots, slowing erosional processes (Rowntree and Dollar 1999).	More floodbench woody vegetation = less bank erosion.

5.3.3 Bed sediment size

The bed sediment size varies spatially, resulting in a range of habitat types for aquatic organisms. The median size of the sediment can change over time as the balance in sediment supply or transport energy shifts. Dams act as sediment retention facilities, with larger dams being more efficient at trapping both coarse and fine sediment, whereas smaller dams are less effective in trapping fine suspended sediment due to the shorter residence time of flows (Fryirs and Brierley 2013; Schmutz and Moog 2018). This leads to a shift to fine sediment inputs only and resultant bed load starvation of downstream reaches with the system becoming supply limited. The reduction in sediment supply will result in the coarsening of the bed to form a fixed armoured layer consisting of large particles (Brandt 2000).

Increases in the fine sediment supply, through land degradation in the catchment, will accelerate fine sediment deposition, leading to a shift to finer bed material. This will drive embeddedness of coarser material.

The main link related to bed sediment size is the process of bed erosion (bed erosion combines all the links relevant to bed sediment size) (Alekseevskiy *et al.* 2008). The linked indicators for bed sediment size are given in **Table 5.34**.

Table 5.34: The reasons for, and relationship between, indicators linked to bed sediment size

Linked indicator	Reasons	Relationship
Bed erosion	The process of bed erosion indicates if a system is losing finer sediment, or gaining finer sediment, thus related to bed sediment size.	More bed erosion = larger sediment size.

5.3.4 Embeddedness

Embeddedness is the measure to which interstitial spaces between larger clasts are filled with fine sediment (sand, silt and clay), smothering coarse habitat associated with riffles, runs, glides and pools (Huchzermeyer and Rowntree 2021). This indicator shows the extent to which coarse habitats are filled in or covered with fine sediment and not available to biota. The main indicators driving embeddedness are finer sediment supply (sand, silt and clay) and bed erosion (embeddedness and fine sediment concentration on the bed is negatively correlated with flow velocity (Huchzermeyer and Rowntree 2021). Dams often change flow and sediment throughput, changing the degree of embeddedness. Reductions in fine sediment supply below dams can lead to reduced embeddedness, whereas reductions in flow can increase embeddedness as flow velocities are incompetent to transport the fine sediment (Sennatt *et al.* 2006).

The linked indicators for embeddedness are given in **Table 5.35**.

Table 5.35: The reasons for, and relationship between, indicators linked to embeddedness

Linked indicator	Reasons	Relationship
Clay, silt and FPOM supply	The supply of fine sediment is a direct driver of fine sediment deposition over coarser substrates (Huchzermeyer and Rowntree 2021; Sennatt et al. 2006).	More fine sediment = more embeddedness.
Sand and gravel supply	The supply of medium sized sediment is a direct driver of sand sized sediment deposition over coarser substrates (Sennatt et al. 2006)	More sand and gravel = more embeddedness.
Bed erosion	Erosion removes fine sediment reducing the level of embeddedness (Huchzermeyer and Rowntree 2021; Sennatt et al. 2006).	More bed erosion = less embeddedness.

5.3.5 Pool depth

Pools are important resting and hiding habitat for fish and invertebrates, especially during low flows and droughts. Geomorphic pool depth indicates the depth or extent of deep slow flowing habitat during low flow or in relation to the relative riffle elevation. Pools are maintained by large floods and can sediment up when floods are reduced or bed sediment input increases (Kuhnle 1996; Lisle and Hilton 1992).

The linked indicators for pool depth are given in **Table 5.36**.

Table 5.36: The reasons for, and relationship between, indicators linked to pool depth

Linked indicator	Reasons	Relationship
Sand and gravel supply	Pool depth responds to sediment loads (Lisle and Hilton, 1992). The higher the sediment loads the higher the potential for sedimentation in pools.	More sand and gravel supply = shallower pool depth.
Bed erosion	Bed erosion scours and maintains pool depth and habitat	More bed erosion = deeper pool depth.

5.3.6 Backwaters and secondary channels

Backwaters and secondary channels are slow flowing habitats along the channel margins or on the flood features, that may fill in with sediment to become unavailable. The main drivers affecting backwaters and secondary channels are sand and gravel supply and bed erosion. Bed erosion is largely driven by flood magnitude whereby large magnitude low frequency events scour and reset the channel planform, scouring secondary channels along the margins that act as backwaters when inundated (Entwistle *et al.* 2015; Heritage *et al.* 2015; Rountree *et al.* 2000). This dynamic is shown in **Figure 5.47** where reductions in flood magnitude will result in low relief and sedimented habitats with less backwaters and secondary channels (Milan *et al.* 2018b). Aquatic vegetation along the margins and in backwaters will increase the roughness and increase sediment deposition, reducing the depth of backwaters and secondary channels (Rominger *et al.* 2010).

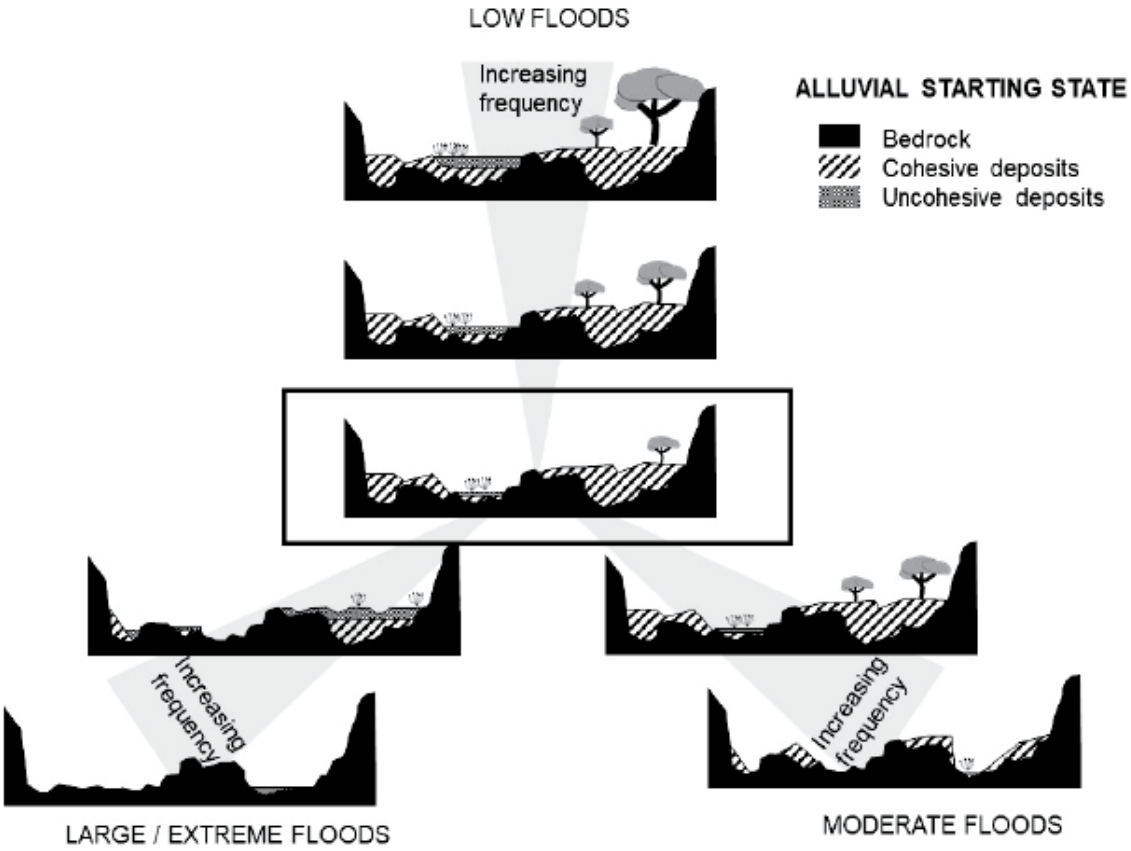


Figure 5.47: The effect of flood size and frequency on channel geomorphology (Milan et al. 2018b, 2018a, 2020)

The linked indicators for backwaters and secondary channels are given in **Table 5.37**.

Table 5.37 The reasons for, and relationship between, indicators linked to backwaters and secondary channels

Linked indicator	Reasons	Relationship
Dry min 5d Q	At lower flows, there are no backwaters, but with increases in dry season flows, a greater proportion of marginal habitat (active channel width) is engaged (Goudie 2004; Hugget and Shuttleworth 2022). Higher dry season flows are also important because they will maintain backwaters and pools through sub-surface flow.	Higher discharge = more backwaters and secondary channels.
Wet max 5d Q	The higher the maximum flows in the river, the greater the extent of inundation of the backwaters. Lower peak flows will limit the extent of seasonal inundation. Flood flows also scour the backwaters and secondary channels, increasing the volume and density of these features, but the features can fill in during lower flows (Milan et al. 2018a, 2018b, 2020).	Higher discharge = more backwaters and secondary channels.
Bed erosion	Increased bed erosion will lead to erosion and opening up of secondary channels (Milan et al. 2018b). Reducing erosion will infill channels leading to water entering the backwater at a relatively lower flood volume.	More bed erosion = more backwaters and secondary channels.
Aquatic vegetation	Increases in aquatic vegetation will reduce flow velocities and increase sedimentation and the volume of the backwater area (Milan et al., 2020; Rominger et al., 2010).	More aquatic vegetation = less backwaters and secondary channels.
Marginal zone graminoids	Increases in marginal vegetation will reduce erosion along the backwater or secondary channel and reduce the scour (Milan et al., 2020)	More marginal zone graminoids = less backwaters and secondary channels.

5.3.7 Inset benches and bars

Inset benches and bars are the areas of the fine sediment deposits along the channel margin or pools that are inundated by freshets. The inset benches are colonised by marginal vegetation and form a habitat for a range of biota during freshets and smaller floods. Sand bars can play a similar role, but are less often colonised by vegetation as they are frequently reworked. Moderate floods would build the inset benches and sand bars (depositing sediment on the margins and in the lee of the islands), whilst extremely large floods would erode the bars and benches (Milan *et al.* 2018a, 2018b, 2020). Inset benches and sand bars tend to be a dynamic features related to recent flows (Dollar and Rowntree 2003).

The linked indicators for inset bench and bars are given in **Table 5.38**.

Table 5.38: The reasons for, and relationship between, indicators linked to inset benches and bars

Linked indicator	Reasons	Relationship
Wet max inst 5d Q	Moderate floods would build the bench and sand bars (depositing sediment on the margins and in the lee of the islands), whilst extremely large floods would erode the bars and benches (Milan et al. 2018a, 2018b, 2020).	Higher discharge = fewer inset benches and bars.
Bank erosion	High bank erosion rates will remove the bars and floodbenches; low erosion will allow the development of new bars and benches.	More bank erosion = fewer inset benches and bars.

5.3.8 Inundated sandy habitat

Inundated sandy habitat refers to inset benches and sand bars that are partly or entirely inundated by water. The indicators driving the extent and availability of inundated sandy habitat are largely hydrological, with higher levels of flow inundating larger areas of sandy habitat (Goudie 2004). Bed erosion can scour the sandy habitats, leading to a reduction in inundated area (Milan *et al.* 2020).

The linked indicators for inundated sandy habitat are given in **Table 5.39**.

Table 5.39: The reasons for, and relationship between, indicators linked to inundated sandy habitat

Linked indicator	Reasons	Relationship
Dry duration	The shorter the dry season, the longer the time that the sand bars are inundated.	Longer dry season = less inundated sandy habitat.
Dry average daily volume	The higher the dry season flow, the larger the area of sandy areas inundated (Goudie 2004).	Larger average daily volume = more inundated sandy habitat.
Wet average daily volume	Wet average daily volume: The higher the wet season flow, the larger the area of sandy areas inundated (Goudie 2004). This link is only for inundation (transport is dealt with by erosion).	
Bed erosion	Increased erosion will remove the sand deposits and reduce the availability of sandy areas. All seasons, so compound effect.	More bed erosion = less inundated sandy habitat.

5.3.9 Inundated cobble habitat

Cobble habitat is critical for the life cycles of fish and invertebrates. These habitats are only available when inundated by water. The indicators driving the extent and availability of inundated cobble habitat are largely hydrological, with higher levels of flow inundating larger areas of cobble habitat (Goudie 2004). Bed erosion can scour the cobble habitats, leading to a reduction in the cobble bar extent that can be inundated (Milan *et al.* 2020).

The linked indicators for inundated cobble habitat are given in **Table 5.40**.

Table 5.40: The reasons for, and relationship between, indicators linked to inundated cobble habitat

Linked indicator	Reasons	Relationship
Dry duration	The shorter the dry season, the longer the time that the cobble bars are inundated	Longer dry season = less inundated cobble habitat.
Dry average daily volume	The higher the dry season flow, the larger the area of cobbly areas inundated (Goudie 2004).	Larger average daily volume = more inundated cobble habitat.
Wet average daily volume	The higher the wet season flow, the larger the area of cobbly areas inundated (Goudie 2004). This link Is only for inundation (transport is dealt with by erosion).	
Bed erosion	Increased erosion will remove the cobble deposits and reduce the availability of cobbly areas. All seasons, so compound effect.	More bed erosion = less inundated cobble habitat.

5.3.10 Riffles

Riffles are coarse sediment habitats with fast shallow flow. The indicators that influence their availability are the flow depth during the dry period and the extent of inundated cobble habitat. These are largely hydrological indicators that track the inundation of the features (see the hydraulic data for each site).

The linked indicators for riffles are given in **Table 5.41**.

Table 5.41: The reasons for, and relationship between, indicators linked to riffles

Linked indicator	Reasons	Relationship
Dry Ave depth	Reductions in the dry season average depth will reduce the extent of riffles.	Shallower depth = fewer riffles.
Inundated cobble habitat	Reductions in the inundated cobble habitat will reduce the extent of riffle habitat available.	More inundated cobble habitat = more riffles.

5.3.11 Floodbenches

Floodbenches are flood features that are inundated during high flows. The indicators that drive floodbenches are flood flows that erode these sediment stores (Milan *et al.* 2018a, 2018b, 2020) and high sand supply that drives sediment deposition to form floodbenches (Fryirs and Brierley 2013).

The linked indicators for riffles are given in **Table 5.42**.

Table 5.42: The reasons for, and relationship between, indicators linked to floodbenches

Linked indicator	Reasons	Relationship
Wet max depth	Increases in maximum flow depths will erode floodbenches (Milan et al., 2018a, 2018b, 2020).	Deeper wet maximum depths of flow = fewer floodbenches.
Sand and gravel supply	Increases in sand and gravel supply during high flow periods will increase the rate of floodbench deposition increasing the extent of floodbenches	More sand and gravel supply = more floodbenches.

5.4 Status and trends

5.4.1 Bed erosion

Relevant at all EWR sites.

The main anthropogenic drivers of indicator status were:

- Changes to land cover (runoff efficiency) and flood flows as these large events drive bed scour and sediment transport. Increases in impervious surface, hillslope channel connectivity, bare soil and stormwater drains will increase the magnitude of flood flows, whereas dams and weirs will lower the magnitude of flood flows.
- Changes to bed sediment input, with landscape degradation and rubble dumping in the channel increasing bedload, and dams and weirs decrease bedload availability.

Assuming the 2022 quantity of bed erosion was 100%, the estimated quantity in:

c. 1900 was:

- 105% at 2_Rietfontein, because the flood magnitude was greater resulting in greater shear stress before farm dams were installed.
- 105% at 6_Kolope, because the flood flow magnitude was greater. The observed incision is not purely a function of changed hydrology, but rather due to the nick point migration from downstream in 1955.
- 105% at 7_Sand, because the flood flows were larger.
- 103% at 13_Mutale1 and 14_Mutale2, because the flood flows were larger.
- 110% at 4_Mogalakwena1 because the flood flows were much larger and the bed sediment supply was uninterrupted.
- 93% at 9_Ṅwaneḍi, 8_Nzhelele and 12_Luvuvhu because the bed sediment supply was much larger.
- 102% at 11_Mutshindudi and 5_Mogalakwena2 because the flood flows were larger.
- 105% at 10_Latonyanda, 3_Olifantspruit, and 1_Lephalala, because the flood flows were much larger driving increased shear stress on the bed.

c. 1960 was:

- 104% in 2_Rietfontein, because the flood magnitude was greater resulting in greater shear stress.
- 103% in 6_Kolope, because the flood flow magnitude was greater. The observed incision is not a function of changed hydrology, but rather due to the nick point migration from downstream in 1955.
- 104% in 7_Sand, because the flood flows were larger.
- 102% in 13_Mutale1 and 14_Mutale2, because the flood flows were larger.

- 98% in 8_Nzhelele (Dam construction 1948), and 12_Luvuvhu (Dams constructed from 1952-2005), because the bed sediment supply was interrupted by reductions in supply.
- 93% in 9_Ṅwaneḍi (Dams constructed in 1964-1975), because the bed sediment supply was uninterrupted.
- 101% in 11_Mutshindudi, 5_Mogalakwena2 and 4_Mogalakwena1 (Dam constructed 1945-1952) because the flood flows were larger.
- 104% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were much larger driving increased shear stress on the bed.

c. 2000 was:

- 103% in 2_Rietfontein because the flood magnitude was greater resulting in greater shear stress.
- 102% in 6_Kolope, because the flood flow magnitude was greater.
- 102% in 7_Sand, because the flood flows were larger.
- 101% in 13_Mutale1 and 14_Mutale2, because the flood flows were larger.
- 100% in, 8_Nzhelele (dam constructed in 1948), 11_Mutshindudi (Dam constructed in 1985), 4_Mogalakwena1 and 5_Mogalakwena2, because the flood magnitude and frequency was reduced and bed sediment supply was interrupted with reductions in supply.
- 99% in 9_Ṅwaneḍi and 12_Luvuvhu, because the flood flows were much larger and the bed sediment supply was uninterrupted.
- 102% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were much larger driving increased shear stress on the bed.

5.4.2 Bank erosion

Relevant at all EWR sites.

The main anthropogenic drivers of indicator status were:

- Changes to land cover and resultant flood flows as these large events drive bank scour and sediment transport. Increases in impervious surface, hillslope-channel connectivity, bare soil and stormwater drains will increase the magnitude of flood flows, whereas dams and weirs will lower the magnitude of flood flows.
- Changes to suspended sediment input, with landscape degradation increasing suspended sediment.
- Trampling along the banks by grazers and browsers.

Assuming the 2022 quantity of bank erosion was 100%, the estimated quantity in:

c. 1900 was:

- 105% in 2_Rietfontein, because the flood magnitude was greater driving bank erosion.
- 105% in 6_Kolope, because the flood flows were more extreme. The incision and associated bank erosion is a function of nick point migration from downstream and not changes in hydrology.
- 105% in 7_Sand, because the flood flows were larger and the sediment input less.
- 103% in 13_Mutale1 and 14_Mutale2, because the flood flows were larger.
- 96% in 8_Nzhelele (Dam constructed in 1948) and 12_Luvuvhu (Dams constructed from 1952-2005) and 5_Mogalakwena2, because the suspended sediment supply was uninterrupted by dams and trampling along the banks was less.

- 96% in 9_Ṅwaneḍi (Dams constructed in 1964-1975), because the bed sediment supply was uninterrupted.
- 103% in 11_Mutshindudi and 4_Mogalakwena1 because the flood flows were higher but trampling and vegetation cover was greater, slowing bank erosion to some degree.
- 105% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were larger with improved vegetation cover stabilising the banks.

c. 1960 was:

- 104% in 2_Rietfontein because the flood magnitude was greater.
- 104% in 6_Kolope, because the flood flows were more extreme. The incision and associated bank erosion is a function of nick point migration from downstream and not changes in hydrology.
- 103% in 7_Sand, because the flood flows were larger and the sediment input less.
- 102% in 13_Mutale1 and 14_Mutale2, because the flood flows were larger.
- 96% in 9_Ṅwaneḍi (Dams constructed in 1964-1975), 12_Luvuvhu (Dams constructed from 1952-2005), and 5_Mogalakwena2 (Dam constructed in 1968), because the suspended sediment supply was uninterrupted by dams.
- 100% in 8_Nzhelele (Dam constructed in 1948) and 4_Mogalakwena1 (Dams constructed 1945-1952) because the suspended sediment supply was uninterrupted by dams.
- 101% in 11_Mutshindudi (Dam constructed in 1985), because the flood flow were higher but trampling and vegetation cover was greater, slowing bank erosion to some degree.
- 103% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were larger with improved vegetation cover stabilising the banks.

c. 2000 was:

- 102% in 2_Rietfontein because the flood magnitude was greater.
- 104% in 6_Kolope, because the flood flows were more extreme. The incision and associated bank erosion is a function of nick point migration from downstream and not changes in hydrology.
- 102% in 7_Sand, because the flood flows were larger and the sediment input less.
- 101% in 13_Mutale1 and 14_Mutale2, because the flood flows were larger.
- 100% in 9_Ṅwaneḍi, 8_Nzhelele, 12_Luvuvhu, 11_Mutshindudi, 4_Mogalakwena1 and 5_Mogalakwena2, because the flood magnitude was reduced and trampling increased.
- 102% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were larger with improved vegetation cover stabilising the banks.

5.4.3 Bed sediment size

Relevant at all EWR sites, except the non-perennial sites 6_Kolope, 7_Sand and 2_Rietfontein.
The main anthropogenic drivers of indicator status were:

- Changes to land cover and land use that increase the fine sediment concentration, such as agriculture, forestry, low vegetation cover and increased landscape connectivity.
- Reductions in flow that reduce transport energy.
- Changes to the river channel that increase or decrease sediment deposition.
- Sand mining removes a particular sediment size and resuspend fine sediment.

Assuming the 2022 quantity of bed sediment size was 100%, the estimated quantity in:

c. 1900 was:

- 103% in 13_Mutale1, 11_Mutshindudi and 14_Mutale2, because the flood flows were larger and the fine sediment input was less.
- 98% in 9_Ṅwaneḍi, 8_Nzhelele, 12_Luvuvhu because the bed sediment supply was uninterrupted by dams.
- 103% in 11_Mutshindudi, 5_Mogalakwena2 and 4_Mogalakwena1 because the flood flows were larger and the bed sediment supply was uninterrupted.
- 109% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were larger with less fine sediment input.

c. 1960 was:

- 102% in 13_Mutale1, and 14_Mutale2, because the flood flows were larger and the fine sediment input was less.
- 99% in 9_Ṅwaneḍi (Dams constructed in 1964-1975) and 12_Luvuvhu (Dams constructed from 1952-2005) because the bed sediment supply was uninterrupted by dams.
- 103% in 11_Mutshindudi and 5_Mogalakwena2 because the flood flows were larger and the bed sediment supply was uninterrupted.
- 100% in 8_Nzhelele (Dam constructed in 1948), 4_Mogalakwena1 (Dams constructed in 1945-1952) because the bed sediment supply was uninterrupted by dams.
- 104% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were larger with less fine sediment input.

c. 2000 was:

- 101% in 13_Mutale1 and 14_Mutale2, because the flood flows were larger and the fine sediment input was less.
- 100% in 9_Ṅwaneḍi, 8_Nzhelele, 12_Luvuvhu, 11_Mutshindudi, 4_Mogalakwena1 and 5_Mogalakwena2, because the flood flows and bed sediment supply were reduced by the dams. High fine sediment input from incremental catchment where land degradation is taking place.
- 102% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were larger with less fine sediment input.

5.4.4 Embeddedness

Relevant at all EWR sites, except 2_Rietfontein.

The main anthropogenic drivers of indicator status are:

- Changes to land cover and land use that increases the fine sediment concentration, such as agriculture, forestry, low vegetation cover and increased landscape connectivity.
- Reductions in flow that reduce transport energy.
- Changes to the river channel that increase or decrease sediment deposition.
- Sand mining that removes a particular sediment size and re-suspend fine sediment. This sediment is likely to be deposited on coarse habitat during low flows.

Assuming the 2022 quantity of embeddedness was 100%, the estimated quantity in:

c. 1900 was:

- 95% in 6_Kolope, because the catchment was not as degraded with less fine sediment input to the reach.
- 95% in 7_Sand, because the flood flows were larger and more sustained and the fine sediment supply was less.

- 96% in 13_Mutale1 and 14_Mutale2, because the flood flows were larger and the fine sediment input was less.
- 90% in 9_Ṅwaneḍi, 11_Mutshindudi, 5_Mogalakwena2, 12_Luvuvhu and 4_Mogalakwena1 because the shear stress was higher during low flows preventing fine sediment deposition.
- 99% in 8_Nzhelele, because the shear stress was higher during low flows preventing fine sediment deposition.
- 95% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were larger with less fine sediment input.

c. 1960 was:

- 96% in 6_Kolope, because the catchment was not as degraded with less fine sediment input to the reach.
- 97% in 7_Sand, because the flood flows were larger and more sustained and the fine sediment supply was less.
- 97% in 13_Mutale1 and 14_Mutale2, because the flood flows were larger and the fine sediment input was less.
- 94% in 9_Ṅwaneḍi, 11_Mutshindudi and 5_Mogalakwena2 because the shear stress was higher during low flows preventing fine sediment deposition with increases in fine sediment input from increased catchment degradation.
- 90% in 12_Luvuvhu (dams constructed from 1952-2005) because the shear stress was higher during low flows preventing fine sediment deposition with increases in fine sediment input from increased catchment degradation.
- 100% in 8_Nzhelele (Dam constructed in 1948) and 4_Mogalakwena1 (Dams constructed 1945-1952) because the shear stress was reduced during low flows preventing fine sediment deposition, balanced by reduced fine sediment concentrations.
- 97% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were larger with less fine sediment input.

c. 2000 was:

- 98% in 6_Kolope, because the catchment was not as degraded with less fine sediment input to the reach.
- 99% in 7_Sand, because the flood flows were larger and more sustained and the fine sediment supply was less.
- 98% in 13_Mutale1 and 14_Mutale2, because the flood flows were larger and the fine sediment input was less.
- 100% in 8_Nzhelele (Dam constructed in 1948), 9_Ṅwaneḍi, 4_Mogalakwena1, 5_Mogalakwena2 (Dam constructed in 1968) and 11_Mutshindudi (Dam constructed in 1985) because the shear stress was reduced during low flows preventing fine sediment deposition, balanced by reduced fine sediment concentrations.
- 90% in 12_Luvuvhu (dams constructed from 1952-2005) because the shear stress was higher during low flows preventing fine sediment deposition with increases in fine sediment input from increased catchment degradation.
- 99% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were larger with less fine sediment input.

5.4.5 Pool depth

Relevant at all EWR sites.

The main anthropogenic drivers of indicator status were:

- Changes to land cover and land use that increases the fine sediment concentration, such as agriculture, forestry, low vegetation cover and increased landscape connectivity.
- Reductions in flow that reduce transport energy.
- Changes to the river channel that increase or decrease sediment deposition.
- Sand mining that removes a particular sediment size and re-suspend fine sediment.

Assuming the 2022 quantity of pool depth was 100%, the estimated quantity in:

c. 1900 was:

- 110% in 2_Rietfontein, because the flood magnitude was greater with less fine sediment input.
- 103% in 6_Kolope, because the flood flows were greater and the sediment input from the catchment was less.
- 102% in 7_Sand, because the flood flows were larger and the fine sediment supply was less.
- 103% in 13_Mutale1 and 14_Mutale2, because the flood flows were larger and the sediment input was less.
- 102% in, 11_Mutshindudi, 4_Mogalakwena1 and 5_Mogalakwena2, because the flood flows were much larger.
- 95% in 9_Ṅwaneḍi, 8_Nzhelele and 12_Luvuvhu because the bed erosion was less before the dam interrupted the sediment supply.
- 105% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were larger with less fine sediment input.

c. 1960 was:

- 108% in 2_Rietfontein, because the flood magnitude was greater with less fine sediment input.
- 103% in 6_Kolope, because the flood flows were greater and the sediment input from the catchment was less.
- 99% in 7_Sand, because the flood flows were larger and the fine sediment supply was less.
- 102% in 13_Mutale1 and 14_Mutale2, because the flood flows were larger and the fine sediment input was less.
- 100% in 8_Nzhelele (Dam constructed in 1948), 4_Mogalakwena1 (Dams constructed from 1945-1952), because the dam interrupted the bed sediment supply.
- 95% in 9_Ṅwaneḍi (Dams built from 1964 – 1975), 12_Luvuvhu (Dams built from 1952-205), because the bed erosion was less before the dam interrupted the sediment supply.
- 101% in 11_Mutshindudi and 5_Mogalakwena2, because the flood flows were much larger and the sediment supply was uninterrupted by dams.
- 103% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were larger with less fine sediment input.

c. 2000 was:

- 105% in 2_Rietfontein, because the flood magnitude was greater with less fine sediment input.
- 103% in 6_Kolope, because the flood flows were greater and the sediment input from the catchment was less.
- 99% in 7_Sand, because the flood flows were larger and the fine sediment supply was less.

- 101% in 13_Mutale1 and 14_Mutale2, because the flood flows were larger and the fine sediment input was less.
- 96% in 12_Luvuvhu (Dams built from 1952-205), because the bed erosion was less before the dam interrupted the sediment supply.
- 100% in, 11_Mutshindudi (Dam constructed in 1985), 4_Mogalakwena1 and 5_Mogalakwena2, because the flood flows were reduced.
- 100% in 9_Ṅwaneḍi, 8_Nzhelele because the bed erosion increased with the dam interrupting the sediment supply.
- 102% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were larger with less fine sediment input.

5.4.6 Backwaters and secondary channels

Relevant at all EWR sites, except the non-perennial sites 6_Kolope, 7_Sand and 2_Rietfontein.

The main anthropogenic drivers of indicator status are:

- Accelerated soil erosion.
- Increased hillslope channel connectivity.
- Decreased longitudinal connectivity due to damming.
- Grazing and trampling by animals.

Assuming the 2022 quantity of backwaters and secondary channels was 100%, the estimated quantity in:

c. 1900 was:

- 102% in 13_Mutale1, 11_Mutshindudi and 14_Mutale2, because of reduced sediment input from the catchment and slightly higher flows.
- 115% in 9_Ṅwaneḍi, 12_Luvuvhu, and 5_Mogalakwena2, because of increased flood flows and higher baseflows making the habitat available.
- 108% in 8_Nzhelele and 4_Mogalakwena1 because of increased flood flows and higher baseflows making the habitat available.
- 108% in 10_Latonyanda and 3_Olifantspruit, because of reduced sediment input from the catchment and increased food flows.
- 132% in 1_Lephalala, because of reduced sediment input from the catchment and increased food flows.

c. 1960 was:

- 101% in 13_Mutale1, 11_Mutshindudi and 14_Mutale2, because of reduced sediment input from the catchment and slightly higher flows.
- 113% in 9_Ṅwaneḍi (Dams constructed 1964-1975), 12_Luvuvhu (Dams constructed from 1952-2005) and 5_Mogalakwena2, because of lower fine sediment input from the incremental catchment and increased flood flows and higher baseflows.
- 100% in 8_Nzhelele (dam constructed 1948) and 4_Mogalakwena1 (Dams constructed from 1945-1952) because of lower flood flows and lower baseflows making the habitat unavailable.
- 104% in 10_Latonyanda and 3_Olifantspruit, because of reduced sediment input from the catchment and increased food flows.

- 120% in 1_Lephalala, because of reduced sediment input from the catchment and increased food flows.

c. 2000 was:

- 100% in 13_Mutale1 and 14_Mutale2, because of reduced sediment input from the catchment and slightly higher flows.
- 102% in 9_Ṅwaneḍi and 5_Mogalakwena2, because of lower sediment input from the incremental catchment and increased flood flows and higher baseflows making the habitat available.
- 100% in 8_Nzhelele, 11_Mutshindudi (Dam built in 1985), 4_Mogalakwena1 and 5_Mogalakwena2 (Dam constructed in 1968), because of reduced increased flood flows maintaining these flood channels and backwaters and lower baseflows making the habitat unavailable.
- 112% in 12_Luvuvhu (Dams built from 1952-2005), because of reduced increased flood flows maintaining these flood channels and backwaters and lower baseflows making the habitat unavailable.
- 102% in 10_Latonyanda and 3_Olifantspruit, because of reduced sediment input from the catchment and increased food flows.
- 110% in 1_Lephalala, because of reduced sediment input from the catchment and increased food flows.

5.4.7 Inset bench and bars

Relevant at all EWR sites, except 7_Sand.

The five main anthropogenic drivers of indicator status were:

- Accelerated soil erosion and change in sediment budget.
- Increased hillslope channel connectivity delivering sediment to the river network.
- Decreased longitudinal connectivity due to damming intercepting sediment.
- Grazing and trampling reduces vegetation cover and increases erosion of these backwater and flood channel areas.

Assuming the 2022 quantity of inset benches and bars was 100%, the estimated quantity in:

c. 1900 was:

- 95% in 2_Rietfontein and 6_Kolope, because of increased flood flows and reduced sediment input from the catchment.
- 98% in 13_Mutale1 and 14_Mutale2, because of reduced sediment input from the catchment, higher flows and more vegetation balancing the nett result.
- 98% in 9_Ṅwaneḍi, 8_Nzhelele, 12_Luvuvhu, 11_Mutshindudi and 4_Mogalakwena1 because of increased flows transporting sediment and scouring pools and the channel margins.
- 90% in 5_Mogalakwena2 because of increased flows transporting sediment and scouring pools and the channel margins.
- 95% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because of reduced sediment input from the catchment and increased food flows.

c. 1960 was:

- 96% in 2_Rietfontein and 6_Kolope, because of increased flood flows and reduced sediment input from the catchment.

- 99% in 13_Mutale1 and 14_Mutale2, because of reduced sediment input from the catchment, higher flows and more vegetation balancing the nett result.
- 98% in 9_Ṅwaneḍi (Dam constructed 1964-1975), 12_Luvuvhu (Dams constructed from 1952-2005) and 11_Mutshindudi because of increased flows transporting sediment and scouring pools and the channel margins.
- 92% in 5_Mogalakwena2 because of increased flows transporting sediment and scouring pools and the channel margins.
- 100% in 8_Nzhelele (Dam constructed 1948) and 4_Mogalakwena1 (Dams constructed from 1945 – 1952) because of reduced flows transporting sediment and scouring pools and the channel margins.
- 97% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because of reduced sediment input from the catchment and increased food flows.

c. 2000 was:

- 98% in 2_Rietfontein and 6_Kolope, because of increased flood flows and reduced sediment input from the catchment.
- 100% in 13_Mutale1 and 14_Mutale2, because of reduced sediment input from the catchment, higher flows and more vegetation balancing the nett result.
- 100% in 9_Ṅwaneḍi, 11_Mutshindudi (Dam constructed in 1985), 4_Mogalakwena1 and 5_Mogalakwena2, because of increased flows transporting sediment and scouring pools and the channel margins.
- 98% in 12_Luvuvhu (Dams constructed from 1952-2005) because of increased flows transporting sediment and scouring pools and the channel margins.
- 100% in 8_Nzhelele (Dam constructed 1948), because of reduced flows transporting sediment and scouring pools and the channel margins.
- 98% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because of reduced sediment input from the catchment and increased food flows.

5.4.8 Inundated sandy habitat

Relevant at all EWR sites

The five main anthropogenic drivers of indicator status were:

- Reduced baseflows drying the habitats out.
- Accelerated soil erosion and change in the sand sediment budget.
- Increased hillslope channel connectivity delivering sediment to the river network.
- Decreased longitudinal connectivity due to damming intercepting sediment.

Assuming the 2022 quantity of inundated sandy habitat was 100%, the estimated quantity in:

c. 1900 was:

- 98% in 2_Rietfontein and 6_Kolope, because catchment degradation was less, reducing the sandy habitat extent.
- 95% in 7_Sand, because of increased flows and less fine sediment input driving increased coarser habitat availability.
- 100% in 14_Mutale2, same as PES (2022), but the sand bars were inundated more frequently.

- 103% in 13_Mutale1, because there was less sand in the system, but the sand bars were inundated more frequently.
- 115% in 9_Ṅwaneḍi and 8_Nzhelele, because of higher base flows making more habitat available.
- 105% in 11_Mutshindudi and 4_Mogalakwena1 because of higher base flows making more habitat available.
- 125% in 5_Mogalakwena2 and 12_Luvuvhu because of higher base flows making more habitat available.
- 110% in 10_Latonyanda and 1_Lephalala, because of higher base flows making more habitat available.
- 103% in 3_Olifantspruit, because of higher base flows making more habitat available.

c. 1960 was:

- 98% in 2_Rietfontein and 6_Kolope, because catchment degradation was less, reducing the sandy habitat extent.
- 97% in 7_Sand, because of increased flows and less fine sediment input driving increased coarser habitat availability.
- 100% in 14_Mutale2, same as PES (2022), but the sand bars were inundated more frequently.
- 102% in 13_Mutale1, because there was less sand in the system, but the sand bars were inundated more frequently.
- 113% in 9_Ṅwaneḍi because of higher base flows making the habitat available.
- 100% in 8_Nzhelele (Dam constructed 1948) and 4_Mogalakwena1 (Dams constructed from 1945 to 1952) because of reduced flows transporting sediment and scouring pools and the channel margins
- 105% in 11_Mutshindudi, because of higher base flows making the habitat available.
- 120% in 5_Mogalakwena2 and 12_Luvuvhu (Dams constructed 1952-2005) because of higher base flows making the habitat available.
- 106% in 10_Latonyanda and 1_Lephalala, because of higher base flows making the habitat available.
- 102% in 3_Olifantspruit, because of higher base flows making the habitat available.

c. 2000 was:

- 99% in 7_Sand and 6_Kolope, because of increased flows and less fine sediment input driving increased coarser habitat availability.
- 100% in 14_Mutale2, same as PES (2022), but the sand bars were inundated more frequently.
- 101% in 13_Mutale1 and 2_Rietfontein, because there more sand in the system, but the existing sand bars were inundated more frequently.
- 100% in 9_Ṅwaneḍi, 8_Nzhelele, 11_Mutshindudi, 4_Mogalakwena1 and 5_Mogalakwena2, because of lower base flows making the less habitat available.
- 115% 12_Luvuvhu (Dams constructed 1952-2005) because of higher base flows making the habitat available.
- 102% in 10_Latonyanda and 1_Lephalala, because of higher base flows making the habitat available.

5.4.9 Inundated cobble habitat

Relevant at all EWR sites, except the non-perennial sites 6_Kolope, 7_Sand and 2_Rietfontein.

The main anthropogenic drivers of indicator status were:

- Increased coarse sediment delivery due to catchment degradation.
- Reduced bedload due to upstream damming.
- Reduced baseflows leading to dry cobbles.

Assuming the 2022 quantity of inundated cobble habitat was 100%, the estimated quantity in:

c. 1900 was:

- 104% in 13_Mutale1 and 14_Mutale2, because of higher flows maintaining cobble habitat and inundating it.
- 106% in 9_Ṅwaneḍi, 8_Nzhelele, 11_Mutshindudi, 4_Mogalakwena1 and 5_Mogalakwena2, because of higher base flows making the habitat available.
- 110% in 10_Latonyanda, 12_Luvuvhu, and 1_Lephalala, because of higher flows maintaining the coarse sediment and inundating the habitat.
- 107% in 3_Olifantspruit, because of higher base flows making the habitat available.

c. 1960 was:

- 103% in 13_Mutale1 and 14_Mutale2, because of higher flows maintaining cobble habitat and inundating it.
- 105% in 9_Ṅwaneḍi (Dams constructed 1964-1975), 11_Mutshindudi and 5_Mogalakwena2, because of higher base flows making the habitat available.
- 100% in 8_Nzhelele (Dam constructed 1948) and 4_Mogalakwena1 (Dams constructed from 1945-1952) because of reduced base flows inundating less of the cobble habitat.
- 107% in 10_Latonyanda and 1_Lephalala, because of higher flows maintaining the coarse sediment and inundating the habitat.
- 110% in 12_Luvuvhu (Dams constructed from 1952-2005) because of higher flows maintaining the coarse sediment and inundating the habitat.
- 105% in 3_Olifantspruit, because of higher base flows making the habitat available.

c. 2000 was:

- 101% in 13_Mutale1 and 14_Mutale2, because of higher flows maintaining cobble habitat and inundating it.
- 100% in 9_Ṅwaneḍi, 8_Nzhelele, 11_Mutshindudi, 4_Mogalakwena1 and 5_Mogalakwena2, because of lower base flows making less of the habitat available.
- 105% in 10_Latonyanda, 12_Luvuvhu (Dams constructed from 1952-2005) and 1_Lephalala, because of higher flows maintaining the coarse sediment and inundating the habitat.
- 103% in 3_Olifantspruit, because of higher base flows making the habitat available.

5.4.10 Riffles

Relevant at all EWR sites.

The main anthropogenic drivers of indicator status were:

- Increased coarse sediment delivery due to catchment degradation
- Reduced bedload due to upstream damming
- Gravel mining
- Increased fine sediment that smothers the cobble habitat.

Assuming the 2022 quantity of riffles was 100%, the estimated quantity in:

c. 1900 was:

- 107% in 2_Rietfontein, because the flood magnitude was greater with less fine sediment input;
- 105% in 6_Kolope, because the system was not incised with a gabion weir, so there was access to upstream riffle habitat.
- 110% in 7_Sand, because the flood flows were larger and the fine sediment supply was less, uncovering coarser sediment along locally steeper sections.
- 106% in 13_Mutale1 and 14_Mutale2, because the flood flows were larger and baseflows higher.
- 105% in 9_Ṅwaneḍi, 8_Nzhelele, and 11_Mutshindudi because the flood magnitude was greater with less fine sediment input from the incremental catchment. Bedload supply was uninterrupted by the Dams.
- 120% in 4_Mogalakwena1, 12_Luvuvhu and 5_Mogalakwena2, because the flood magnitude was greater with less fine sediment input from the incremental catchment. Bedload supply was uninterrupted by the Dams.
- 115% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were larger with less fine sediment input.

c. 1960 was:

- 105% in 2_Rietfontein, because the flood magnitude was greater with less fine sediment input.
- 104% in 6_Kolope, because the system was not incised with a gabion weir, so there was access to upstream riffle habitat.
- 99% in 7_Sand, because the flood flows were larger and the fine sediment supply was less, uncovering coarser sediment along locally steeper sections.
- 104% in 13_Mutale1 and 14_Mutale2, because the flood flows were larger and baseflows higher.
- 105% in 9_Ṅwaneḍi, 11_Mutshindudi, and 5_Mogalakwena2, because the flood magnitude was greater with less fine sediment input from the incremental catchment. Bedload supply was uninterrupted by the Dams.
- 118% in 12_Luvuvhu (Dams constructed from 1952-2005) because the flood magnitude was greater with less fine sediment input from the incremental catchment. Bedload supply was uninterrupted by the upper dam.
- 100% in 8_Nzhelele (Dam constructed in 1948) and 4_Mogalakwena1 (Dams constructed from 1945-1952) because the flood magnitude was reduced and bedload supply was interrupted by the Dams.
- 110% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were larger with less fine sediment input.

c. 2000 was:

- 103% in 2_Rietfontein, because the flood magnitude was greater with less fine sediment input.
- 102% in 6_Kolope, because the system was not incised with a gabion weir, so there was access to upstream riffle habitat.
- 99% in 7_Sand, because the flood flows were larger and the fine sediment supply was less, uncovering coarser sediment along locally steeper sections.
- 102% in 13_Mutale1 and 14_Mutale2, because the flood flows were larger and baseflows higher.
- 100% in 9_Ṅwaneḍi, 8_Nzhelele, 11_Mutshindudi (Dam constructed in 1985), 4_Mogalakwena1 and 5_Mogalakwena2, because the flood magnitude was reduced and bedload supply was interrupted by the Dams.

- 115% in 12_Luvuvhu (Dams constructed from 1952-2005) because the flood magnitude was greater with less fine sediment input from the incremental catchment. Bedload supply was uninterrupted by the upper dam.
- 105% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because the flood flows were larger with less fine sediment input.

5.4.11 Floodbenches

Relevant at EWR sites.

The main anthropogenic drivers of indicator status are:

- Increased fine sediment delivery due to catchment degradation.
- Reduced large flows that scour the features due to upstream damming.
- Sand mining.
- Animal trampling that destabilise the vegetation and benches protecting the banks.

Assuming the 2022 quantity of floodbenches was 100%, the estimated quantity in:

c. 1900 was:

- 95% in 2_Rietfontein and 6_Kolope, because there were larger flood flows in the past.
- 98% in 7_Sand, because of increased flow magnitude driving more frequent bank erosional processes.
- 100% in 13_Mutale1, 11_Mutshindudi and 14_Mutale2, due to increased flows and vegetation cover.
- 103% in 9_Ṅwanedi, 8_Nzhelele, 12_Luvuvhu, because floods inundating the floodbench were more frequent depositing fine sediment on these features.
- 97% in 4_Mogalakwena1 and 5_Mogalakwena2, because flood flows greater eroding the floodbench margins.
- 95% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because bank erosion was more active resulting in a less stable bank and floodbench.

c. 1960 was:

- 97% in 2_Rietfontein and 6_Kolope, because there were larger flood flows in the past.
- 98% in 7_Sand, because of increased flow magnitude driving more frequent bank erosional processes.
- 100% in 13_Mutale1, 11_Mutshindudi and 14_Mutale2, due to increased flows and vegetation cover.
- 103% in 9_Ṅwanedi (dams constructed from 1964-1975), 12_Luvuvhu (Dams constructed from 1952-2005) because floods inundating the floodbench were more frequent depositing fine sediment on these features.
- 99% in 5_Mogalakwena2, because floods inundating the floodbench were slightly reduced, depositing less fine sediment on these features.
- 100% in 8_Nzhelele (Dam constructed in 1948), 11_Mutshindudi, 4_Mogalakwena1 (Dams constructed from 1945-1952) because floods inundating the floodbench were reduced, depositing less fine sediment on these features.
- 97% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because bank erosion was more resulting in a less stable bank and floodbench.

c. 2000 was:

- 98% in 2_Rietfontein and 6_Kolope, because there were larger flood flows in the past.
- 99% in 7_Sand, because of increased flow magnitude driving more frequent bank erosional processes.
- 100% in 13_Mutale1 and 14_Mutale2, due to increased flows and vegetation cover.
- 100% in 9_Ṅwanedi, 8_Nzhelele, 11_Mutshindudi, 4_Mogalakwena1 and 5_Mogalakwena2, because floods inundating and maintaining the floodbenches were less frequent.
- 102% in 12_Luvuvhu (Dams constructed from 1952-2005), because floods inundating the floodbench were more frequent depositing fine sediment on these features.
- 99% in 10_Latonyanda, 3_Olifantspruit and 1_Lephalala, because bank erosion was more resulting in a less stable bank and floodbench.

5.4.12 Summary of trends

A summary of all the trends is provided in **Table 5.43**.

Table 5.43: Summary of trends for all indicators at all sites

Indicator	Year	1_Lephalala	2_Rietfontein	3_Olifantspruit	4_Mogalakwena1	5_Mogalakwena2	6_Kolope	7_Sand	8_Nzhelele	9_Ṅwanedi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale1	14_Mutale2
Bed erosion	1900	105	105	105	110	102	105	105	93	93	105	102	93	103	103
	1960	104	104	104	101	101	103	104	98	93	104	101	98	102	102
	2000	102	103	102	100	100	102	102	100	99	102	100	99	101	101
Bank erosion	1900	105	105	105	103	96	105	105	96	96	105	103	96	103	103
	1960	103	104	103	100	96	104	103	100	96	103	101	96	102	102
	2000	102	102	102	100	100	104	102	100	100	102	100	100	101	101
Bed sediment size	1900	109		109	103	103			98	98	109	103	98	103	103
	1960	104		104	100	103			100	99	104	103	99	102	102
	2000	102		102	100	100			100	100	102	100	100	101	101
Embeddedness	1900	95		95	90	90	95	95	99	90	95	90	90	96	96
	1960	97		97	100	94	96	97	100	94	97	94	90	97	97
	2000	99		99	100	100	98	99	100	100	99	100	90	98	98
Pool depth	1900	105	110	105	102	102	103	102	95	95	105	102	95	103	103
	1960	103	108	103	100	101	103	99	100	95	103	101	95	102	102
	2000	102	105	102	100	100	103	99	100	100	102	100	96	101	101
Backwaters and secondary channels	1900	132		108	108	115			109	115	108	102	115	102	102
	1960	120		104	100	113			100	113	104	101	113	101	101
	2000	110		102	100	102			100	102	102	100	112	100	100
Inset bench and bars	1900	95	95	95	98	90	95		98	98	95	98	98	98	98
	1960	97	96	97	100	92	96		100	98	97	98	98	99	99
	2000	98	98	98	100	100	98		100	100	98	100	98	100	100
Inundated sandy habitat	1900	110	98	103	105	125	98	95	115	115	110	105	125	103	100
	1960	106	98	102	100	120	98	97	100	113	106	105	120	102	100
	2000	102	101		100	100	99	99	100	100	102	100	115	101	100
Inundated cobble habitat	1900	110		107	106	106			106	106	110	106	110	104	104
	1960	107		105	100	105			100	105	107	105	110	103	103
	2000	105		103	100	100			100	100	105	100	105	101	101
Riffles	1900	115	107	115	120	120	105	110	105	105	115	105	120	106	106
	1960	110	105	110	100	105	104	99	100	105	110	105	118	104	104
	2000	105	103	105	100	100	102	99	100	100	105	100	115	102	102
Floodbenches	1900	95	95	95	97	97	95	98	103	103	95	100	103	100	100
	1960	97	97	97	100	99	97	98	100	103	97	100	103	100	100
	2000	99	98	99	100	100	98	99	100	100	99	100	102	100	100

5.5 EcoSpecifications, TPCs and recommendations for monitoring

The methods used to calculate the monitoring data, the PES (2022) values, EcoSpecs, TPCs and recommendation going forward are presented in this section.

5.5.1 Methods used to quantify the monitoring indicators

The following methods should be used to quantify the monitoring indicators.

5.5.1.1 GAI score

The Geomorphic Driver Assessment Index (GAI) is a field-based tool that should be used to determine a site's geomorphological state. The GAI tool is explained by Rowntree (2013) and should be conducted once a year in the dry season. As GAI is subjective, some objective measurements should be included,

such as the channel width to depth ratio, sand bar extent, and mobile sediment size in the riffle to back the GAI scores. As GAI is used to assess a range of scales and processes it is a handy tool to guide possible drivers to the change in geomorphic condition.

5.5.1.2 Channel width to depth ratio

The channel width to depth ratio is a rapid method that quantifies channel width changes and channel depth changes. The ratio is calculated by measuring the bankfull width and maximum depth, see **Figure 5.48**. The width is then divided by the depth to give a ratio. The measurements can be done with a tape measure, or based on the cross sectional survey at a fixed monitoring point.

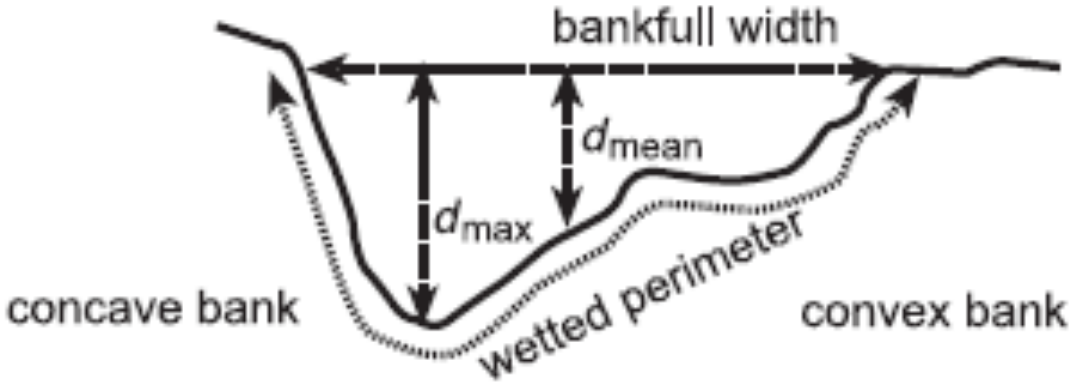


Figure 5.48: Channel cross section indicating bankfull width and maximum depth (Fryirs and Brierley 2013)

5.5.1.3 Sand bar extent in pools during low flow

Sand bars are depositional features along river channels. As they are highly dynamic and driven by sand supply and event hydrology, they are sensitive indicators of recent changes that occurred in the system. As pools are important refuge areas and sand bars in pools can reduce the volume of the pools, they should be monitored. Monitoring can be done from the bank, from oblique photos (drone or from hillside/tree) or aerial/satellite images (**Figure 5.49**).



Figure 5.49: Oblique image of a sand bar (indicated by black hashed line) in a pool of the Lephalala River (inset photo of the same sand bar from the bank)

Oblique and overhead images are better for area estimations. Image dates should be as close as possible to the field work dates and be captured during low flows. In **Figure 5.49** the sand bar extent is estimated around 15 to 20% of the pool area. More accurate calculations can be done in a GIS environment. The sandbar extent in pools should include the pool upstream and downstream of the monitoring site.

5.5.1.4 Mobile sediment size in riffle

Riffles are important habitat for a range of aquatic organisms and require maintenance in terms of flows and sediment supply. Changes to these drivers will be reflected in the size of the mobile sediment along riffles. By monitoring the 16th, 50th and 84th percentile (D_{16}, D_{50} and D_{84} respectively) of the sediment, trends can be tracked over time.

A random selection of 100 particles should be collected from a riffle at the site. The particles are selected by crossing the riffle at 10 evenly spaced transects or following a zigzag pattern across the riffle, picking the particle closest to your large toe/toe of boot for every step (Gordon *et al.* 2004). The B-axis (not the longest or the shortest/thinnest axis of the particle) is measured with a tape measure and recorded. The D_{16}, D_{50} and D_{84} can be calculated in a spreadsheet. Care should be taken not to only select the largest or smallest particles so the readings are unbiased.

5.5.2 Ecospecs and TPCs

The observed values for the ecospecs from August 2022 are presented in **Table 5.44**.

Table 5.44 PES (2022) monitoring values for geomorphology

Site	GAI	WD ratio			Sand bar extent	Riffle/bed sediment size (mm)		
		Width (m)	Depth (m)	WD ratio	% of pool	D16	D50	D84
1_Lephalala	C (76%)	60	2	30	20	9	25	58
2_Rietfontein	C (76%)	20	1.5	13.3	Na	0.25	4	8
3_Olifantspruit	C (76%)	13	1.5	8.7	0	14	27	55
4_Mogalakwena1	C (67%)	55	2.5	22	0	16	30	65
5_Mogalakwena2	D (55%)	46	2	23	10	17	35	55
6_Kolope	D (57%)	25	2.5	10	Na	0.125	0.2	0.3
7_Sand	C (77%)	61	2	30.5	Na	0.125	0.8	2
8_Nzhelele	D (59%)	49	2.8	17.5	5	11	27	82
9_Ṅwanedi	D (57%)	40	3	13.3	25	14	32	59
10_Latonyanda	C (74%)	14	1.5	9.3	5	7	14	56
11_Mutshindudi	C (65%)	32	1.5	21	5	13	25	50
12_Luvuvhu	D (54%)	56	2.5	22.4	15	19	35	59
13_Mutale1	C (72%)	54	1.4	38.5	5	18	32	53
14_Mutale2	C (71%)	38	1.8	21	10	15	24	49

The TPCs for geomorphology are:

- GAI score: A shift of >15%;
- WD ratio shift of >20%;
- A sandbar extent in pools during low flow conditions of >30%; and
- A change in riffle/bed material size of >75%.

5.5.3 Recommendations

The following recommendations should be considered:

- The indicators should be monitored during low base flows.
- The monitoring should be done on an annual to biannual basis.
- A small drone with colour camera should be considered to take oblique and aerial images for monitoring purposes.
- Fixed point photos of the transect from upstream and downstream should be taken for every monitoring trip.
- Bank erosion and embeddedness should be included in the future.
- The data (GAI sheet, all measurements, all photos, notes) should be filed per site, followed by date, and stored on a central server so the data cannot be lost.

6 RIPARIAN VEGETATION

6.1 Introduction

The main objectives of the riparian vegetation study were to 1) determine the PES of riparian vegetation and 2) identify the relationship between riparian vegetation and flow level changes, and to predict what impacts, if any, will occur with changes to the present-day flow regimes.

6.1.1 Assumptions and limitations

The following assumptions apply to the determination of flow requirements for riparian vegetation in this study:

- It is assumed that riparian indicators selected adequately represent the riparian flora.

The following limitations may apply to this study:

- A complete and accurate understanding of the reference condition is difficult although important when calculating the PES.
- Seasonality and seasons within the DRIFT model are hydrologically defined. Temporal aspects related to timing of floods in relation to vegetation processes may not always be well represented.

6.2 EWR sites with a focus on riparian vegetation

6.2.1 Catchment description

At a broad scale, the vegetation is highly uniform, and although 4 different biomes are represented, Savanna dominates the area (**Figure 6.1**; Mucina & Rutherford, 2006; 2018, **Figure 6.2**), with small portions of Grasslands, Forests and Azonal Vegetation. The Savanna Biome comprises the Central Bushveld Bioregion (69% of the study area), the Mopane Bioregion (24%) and the Lowveld Bioregion (6%) with small representation by Alluvial vegetation, Azonal and Zonal & Intrazonal Forests (**Figure 6.2;** Mucina & Rutherford 2006; 2018, **Table 6.1**). Forested areas are incorporated within the Soutpansberg Centre of plant endemism, which dominates the Upper Luvuvhu and Lower Luvuvhu / Mutale IUAs, but also occurs in portions of the Lower Sand, Nzhelele / Ṅwaneḍi and Shingwedzi IUAs (**Figure 6.3).** Thirty different vegetation units occur (**Figure 6.4**) most of which are variations of Bushveld with different characteristics, species compositions / dominance, and geological associations. Smaller portions of notably important units are scattered with Springbokvlakte Thornveld, Waterberg-Magaliesberg Summit Sourveld and Strydpoort Summit Sourveld in the Upper Nyl & Sterk IUA, Soutpansberg Summit Sourveld in the Lower Sand IUA, Northern Mistbelt Forest in the Upper Sand and Upper Luvuvhu IUAs, Ironwood Dry Forest in the Upper Luvuvhu, Lower Luvuvhu / Mutale and Nzhelele / Ṅwaneḍi IUAs, Lowveld Riverine Forest in the Lower Luvuvhu / Mutale IUA and Subtropical Alluvial Vegetation in the Mapungubwe, Lower Luvuvhu / Mutale and Shingwedzi IUAs (**Table 6.2**).

Based on the remaining extent of natural vegetation a few of the IUA's also contain threatened ecosystems (Figure 6.5; SANBI 2011). Critically endangered ecosystems (CR) include Woodbush Granite Grassland in the Upper Sand IUA. Endangered ecosystems (EN) include Blouberg Forest in the Lower Sand and Mogalakwena IUAs and Mapungubwe/Greefswald Riverine Forest in the Mapungubwe IUA within the Mapungubwe National Park along the Limpopo River. Vulnerable ecosystems (VU) include Lowveld Riverine Forest in Kalkpan se Loop, Mapungubwe, Upper Luvuvhu and Lower

Luvuvhu/Mutale IUAs; Springbokvlakte Thornveld in the Upper Nyl & Sterk IUA and; and Tzaneen Sour Bushveld in the Upper Luvuvhu.

Table 6.1: Biome dominance within each IUA (% of total area within IUA)

IUA	Azonal Vegetation	Forests	Grassland	Savanna	Total
Kalkpan se Loop	0.01	0.00	0.00	9.21	9.22
Mapungubwe	0.06	0.00	0.00	3.33	3.40
Lower Lephalala	0.00	0.00	0.00	6.19	6.19
Lower Luvuvhu/ Mutale	0.03	0.02	0.00	6.74	6.79
Lower Sand	0.00	0.00	0.03	14.66	14.69
Mogalakwena	0.00	0.00	0.01	17.94	17.95
Nzhelele/ Ṅwaneḍi	0.00	0.01	0.01	5.48	5.50
Shingwedzi	0.06	0.00	0.00	4.75	4.81
Upper Lephalala	0.00	0.00	0.06	5.73	5.79
Upper Luvuvhu	0.00	0.01	0.00	7.55	7.55
Upper Nyl and Sterk	0.00	0.00	0.14	12.60	12.74
Upper Sand	0.00	0.00	0.18	5.18	5.36
Total	0.16	0.04	0.44	99.36	100.00

Table 6.2: Bioregion dominance within each IUA (% of total area within IUA)

IUA	Alluvial Vegetation	Azonal Forests	Central Bushveld Bioregion	Lowveld Bioregion	Mesic Highveld Grassland Bioregion	Mopane Bioregion	Zonal & Intrazonal Forests	Total
Kalkpan Se Loop	0.01	0.00	6.13	0.00	0.00	3.00	0.00	9.14
Lower Lephalala	0.00	0.00	6.13	0.00	0.00	0.00	0.00	6.14
Lower Luvuvhu/ Mutale	0.03	0.01	1.30	1.61	0.00	4.66	0.01	7.62
Lower Sand	0.00	0.00	11.03	0.00	0.03	3.51	0.00	14.56
Mapungubwe	0.06	0.00	0.00	0.00	0.00	3.30	0.00	3.37
Mogalakwena	0.00	0.00	14.69	0.00	0.01	3.09	0.00	17.79
Nzhelele/ Ṅwaneḍi	0.00	0.00	1.30	0.66	0.01	3.47	0.01	5.46
Shingwedzi	0.06	0.00	0.00	1.82	0.00	2.89	0.00	4.77
Upper Lephalala	0.00	0.00	5.68	0.00	0.06	0.00	0.00	5.74
Upper Luvuvhu	0.00	0.00	4.77	2.70	0.00	0.00	0.00	7.48
Upper Nyl & Sterk	0.00	0.00	12.48	0.00	0.14	0.00	0.00	12.63
Upper Sand	0.00	0.00	5.13	0.00	0.18	0.00	0.00	5.31
Total	0.16	0.01	68.66	6.80	0.44	23.91	0.03	100.00

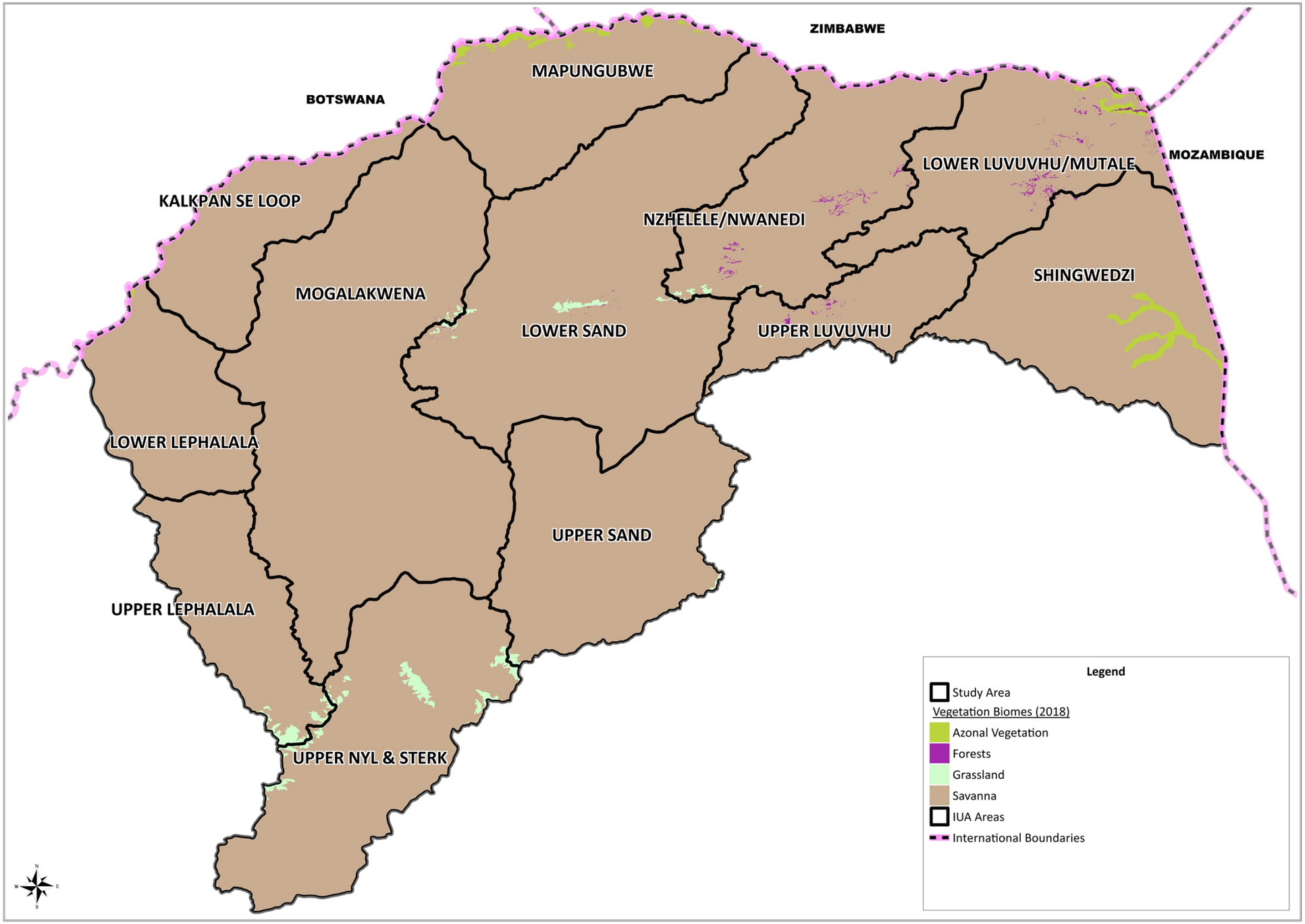


Figure 6.1: Vegetation Biomes within the IUAs of the study area (from Mucina & Rutherford, 2018 update)

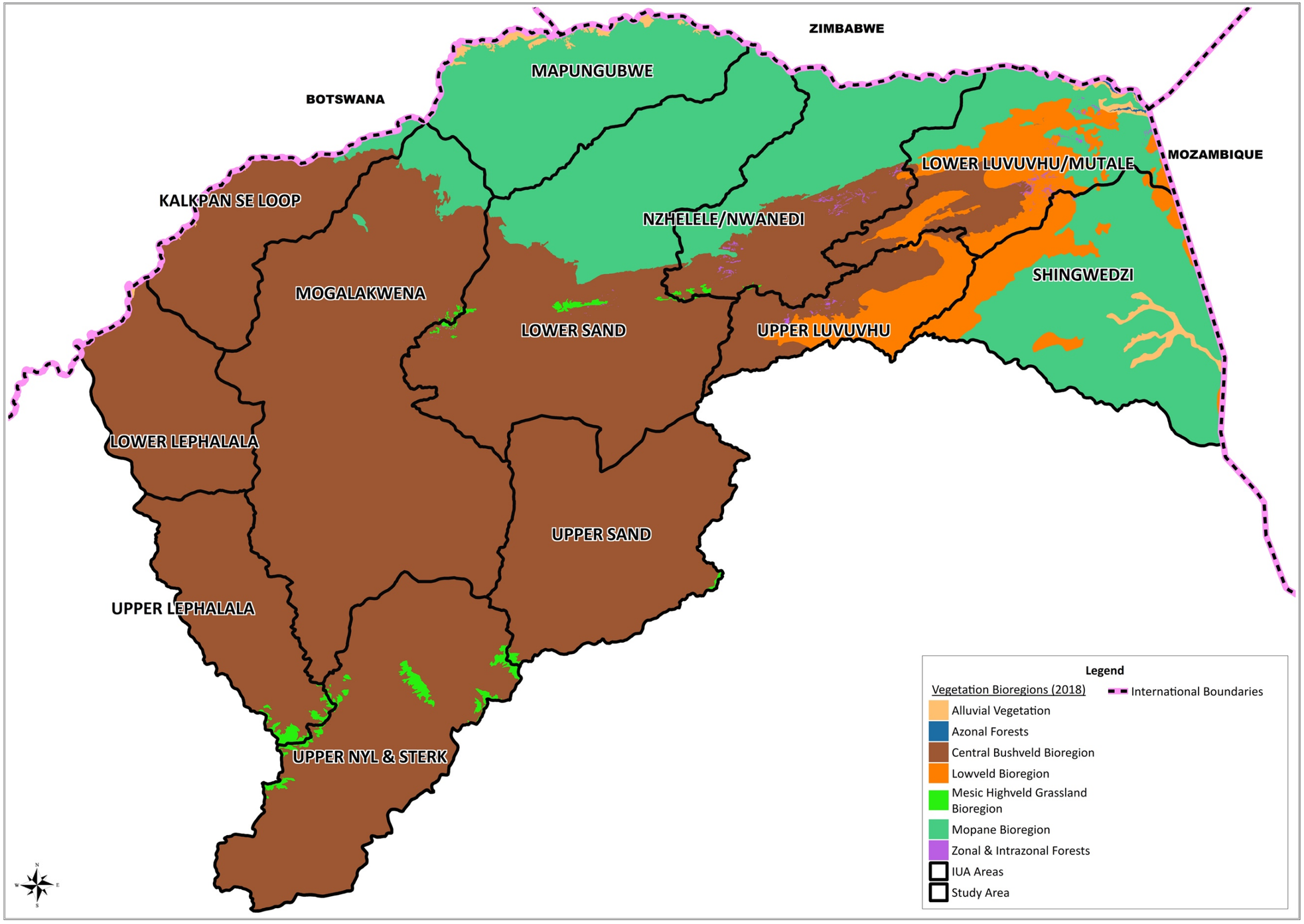


Figure 6.2: Vegetation Bioregions within the IUAs of the study area (from Mucina & Rutherford, 2018 update)

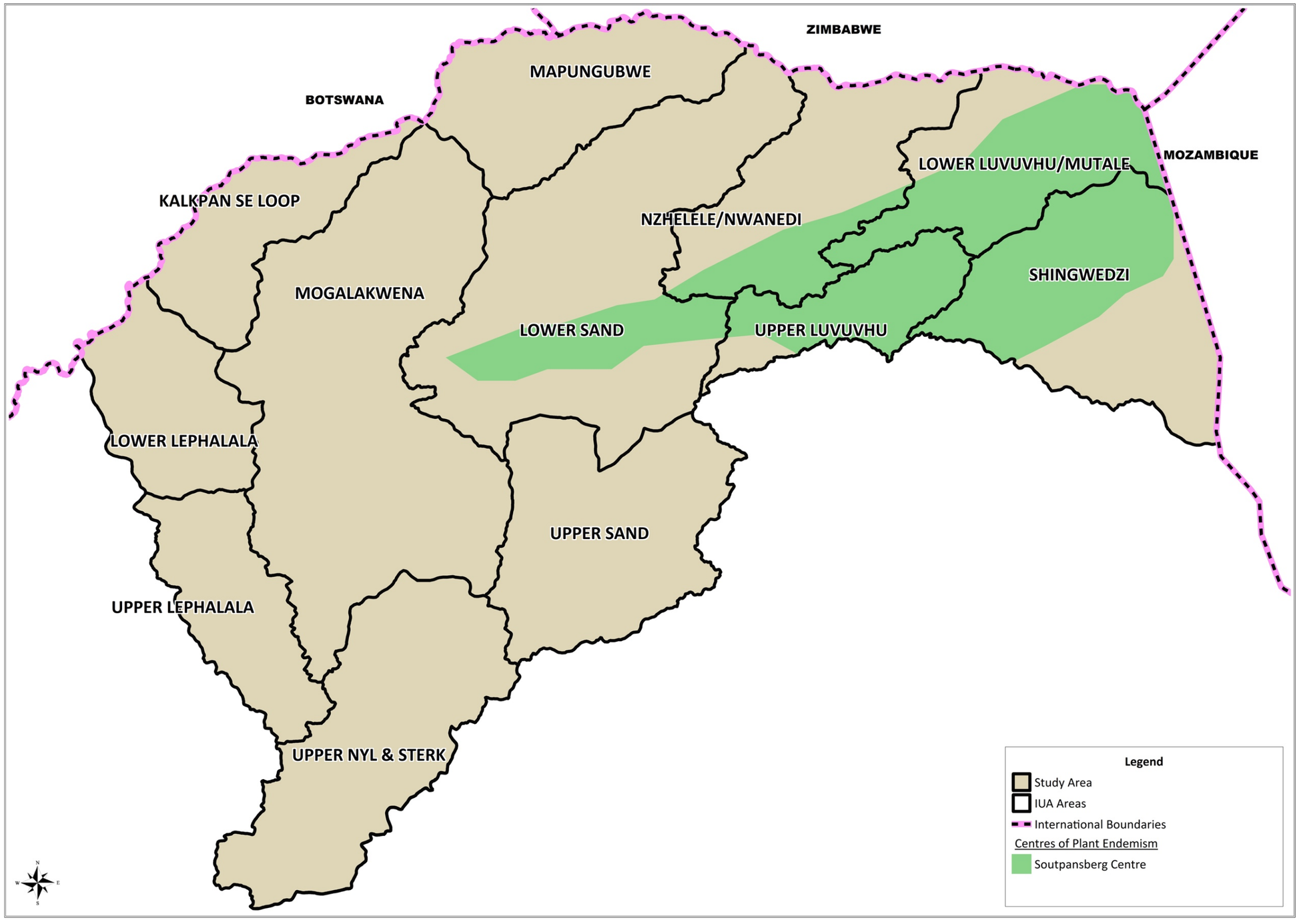


Figure 6.3: The Soutpansberg Centre of plant endemism within the IUAs of the study area

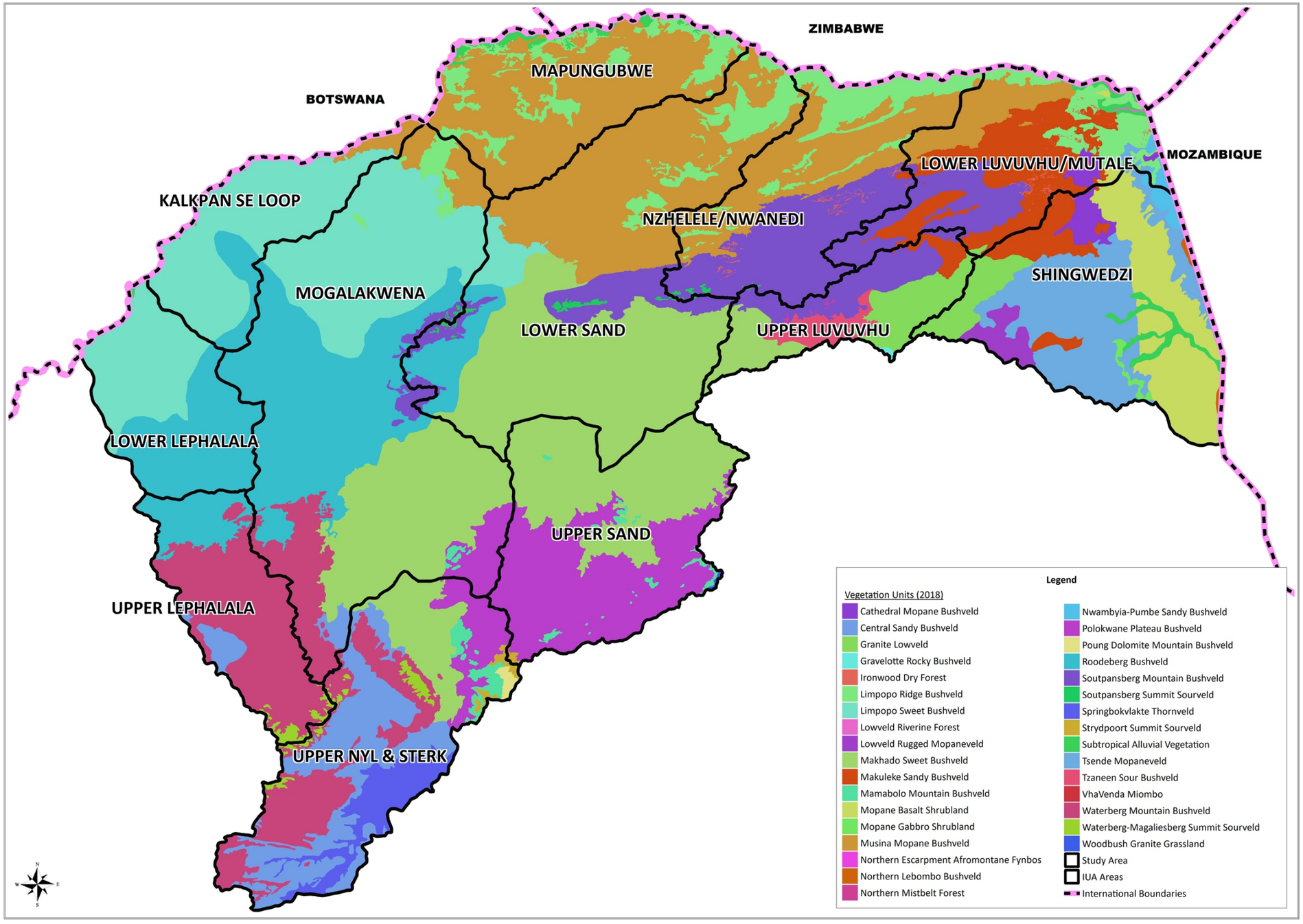


Figure 6.4: Vegetation Units within the IUAs of the study area (from Mucina & Rutherford, 2018 update)

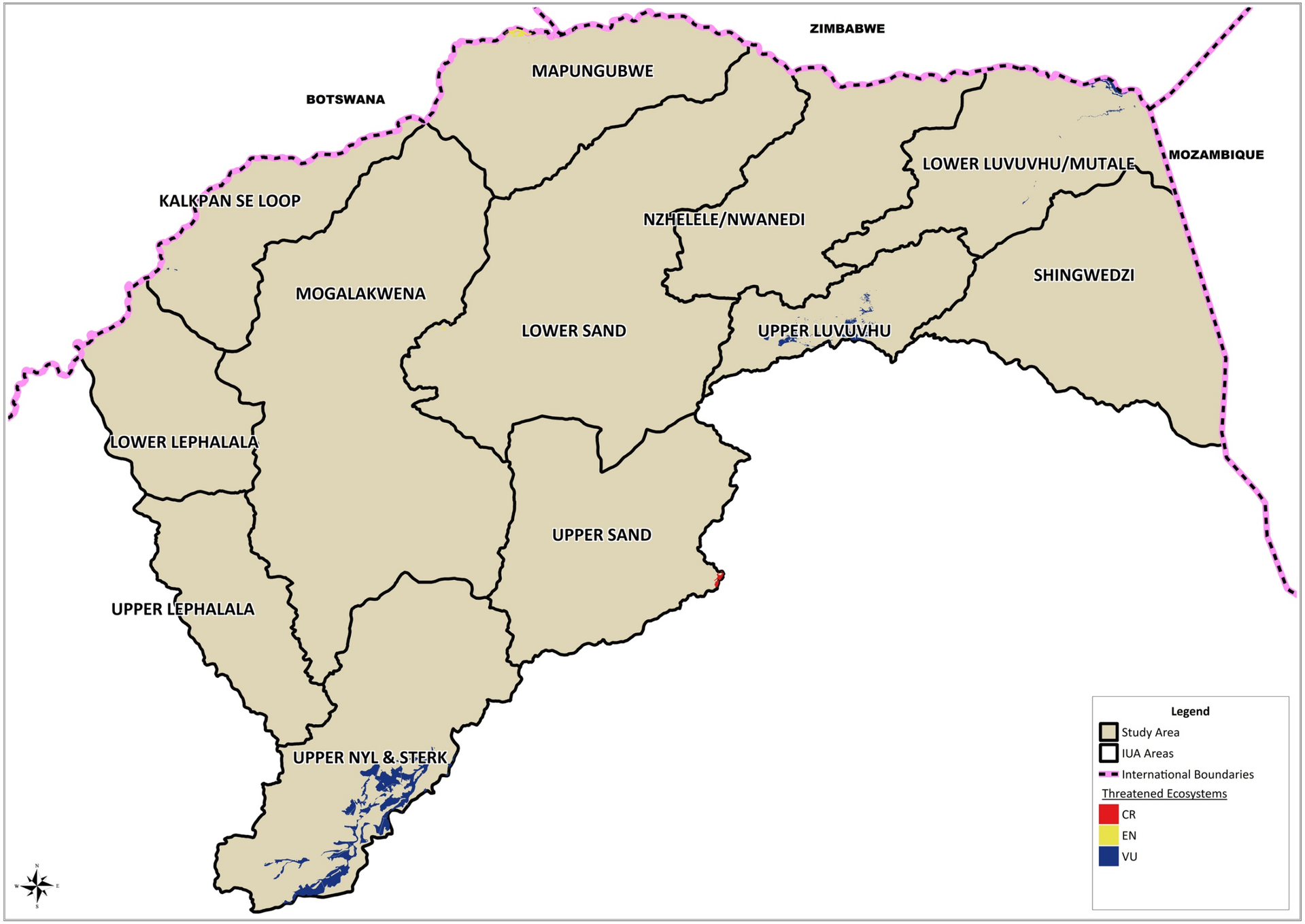


Figure 6.5: Map of threatened ecosystems in relation to IUAs within the study area (SANBI, 2011, remaining extent of natural vegetation)

6.2.2 Data collection and analysis

Data were collected on the abundance of different riparian and aquatic plant species that were used to:

- Describe the Present Ecological Status (PES) using VEGRAI level 4
- Determination of the Ecological Importance (EI)
- Determination of the Ecological Sensitivity (ES)
- Determination of the EWR for riparian vegetation at each site.

The riparian vegetation response assessment index (VEGRAI) is a tool that was designed to rapidly evaluate the ecological status of riparian vegetation (Kleynhans et al. 2007). It requires an understanding of the reference (natural) condition against which change of vegetation structure, composition and distribution are compared. The deviation from the natural condition, in which no anthropogenic impacts occur, is expressed as a percentage score commonly referred to as the Present Ecological State (PES) and can be categorised into meaningful management units (A-F). The PES score itself may be used as a monitoring metric to assess whether overall ecological health changes over time.

Reference conditions were described using historic data and an understanding of impacts that cause change. The following data were used:

- Historic distribution of vegetation Biomes, Bioregions and Types (Mucina & Rutherford 2006, 2012; SANBI 2018).
- Current and historic plant species distribution patterns (POSA; SANBI 2009).
- Grey literature.
- Anecdotal information from any available source, either published (e.g. Skead 2009), by interviews or photographs, all that provide historical context.
- Historic aerial photographs.
- Satellite imagery and Google Earth.
- Personal experience and knowledge.

6.2.3 Description of sites

6.2.3.1 1_Lephalala

Both banks of the riparian area at 1_Lephalala were assessed on 8 August 2022, from pool upstream for a distance of 130 m downstream in four zones: the aquatic, marginal, floodbench and Macro-channel Bank (MCB). The present and reference states for each are described in **Table 6.3** and the ratings of impacts in **Table 6.4**. There were 26 indigenous and 12 alien species (**Table 6.5**). The PES score was 71.9%, an ecological category of C (**Table 6.6**).

Table 6.3: Description of reference and present state for 1_Lephalala

Zone	Description of reference state	Description of present state
 Aquatic zone	The aquatic zone was in a natural state.	The aquatic zone was narrow and in slow flow, scattered between rocks and in the lee of bedrock/boulders or tufted grasses (*Miscanthus junceus*). The main species were *Potamogeton schweinfurthii* and *Stuckenia pectinatus.*
 Marginal zone	The marginal zone should comprise non-woody grasses, sedges, reeds and some woody species such as *Syzygium cordatum, S, guineense* or *Breonadia salicina.* Historical aerial photographs show the cover of reeds in the active channel has increased.	The marginal zone comprised non-woody plants such as reeds (*Phragmites mauritianus*) and tufted and (*M. junceus) creeping grasses (Ischaemum fasciculatum)*, with recruiting saplings of woody *Combretum erythrophyllum*. Alien plants present were *Ageratum houstonianum* and sapling *Eucalyptus camaldulensis.*
 Floodbench	The floodbench should comprise non-woody grasses and sedges with some woody *Combretum erythrophyllum* trees.	The floodbench comprised unvegetated sandy/cobble bars or with tufted grasses (*M. junceus*), short shrubs (*Buxus macowanii*) or young trees (*Combretum erythrophyllum*). There were annual exotic weeds sapling and adult *Eucalyptus camaldulensis* trees.
 MCB	The MCB should comprise riparian woodland/thicket, with short dense shrubs and tall open trees, and some areas where non-woody plants grow.	The MCB was dense and dominated by woody trees and shrubs, including Boscia albitrunca Carissa bispinosa, Dichrostachys cinerea, Terminalia sericea, Vachellia karroo, C. erythrophyllum and Ziziphus mucronata. The alien shrub Lantana camara and tree E. camuldulensis were present.

Table 6.4: Summary of impacts observed at 1_Lephalala

Impacts	Intensity	Extent	Notes
Aquatic zone			
Vegetation Removal	0	0	None
Alien Species Invasion	0	0	None
Terrestrial Species	0	0	None
Water Quantity	1	5	Several small farm dams exist upstream of the site and along tributaries with fairly extensive cultivation, including centre pivots. The site is likely to be affected by abstraction and return flows.
Water Quality	0	5	None
Erosion	0	0	None
Marginal zone			
Vegetation Removal	1.5	2	Cattle trampling and grazing pressure, warthog tillage/ foraging and clearing along localised access paths.
Alien Species Invasion	2.5	3	Alien plant species included Ageratum houstonianum and sapling Eucalyptus camaldulensis.
Terrestrial Species	0	0	None
Water Quantity	1	5	Several small farm dams exist upstream of the site and along tributaries with fairly extensive cultivation, including centre pivots. The site is likely to be affected by abstraction and return flows.
Water Quality	0	5	None
Erosion	0	0	None
Floodbench			
Vegetation Removal	1	1	Cattle trampling and grazing pressure, warthog tillage / foraging and clearing along localised access paths.
Alien Species Invasion	2	3	Alien plant species included Ageratum houstonianum and sapling Eucalyptus camaldulensis.
Terrestrial Species	1	2	Higher than expected for a flood feature
Water Quantity	0	0	None
Water Quality	0	5	None
Erosion	1	1	Access paths
MCB			
Vegetation Removal	1	2	Cattle trampling and grazing pressure, clearing along localised access paths.
Alien Species Invasion	2	3	Alien plant species included Ageratum houstonianum and sapling Eucalyptus camaldulensis.
Terrestrial Species	1	2	Higher density than expected for a flood feature.
Water Quantity	0	0	None
Water Quality	0	5	None
Erosion	1	1	Access paths

Table 6.5: List of plant species observed at 1_Lephalala (Ex. = exotic, P = protected, , y = yes, En. = Endemic, SA = South Africa, SnA = southern Africa)

Species	Family	Common Name/s	Ex.	P	En.
Ageratum houstonianum	ASTERACEAE	Bluemink	*		
Agrostis lachnantha var. lachnantha	POACEAE	Bent grass			
Argemone mexicana	PAPAVERACEAE	Yellow Mexican Poppy	*		
Bidens pilosa	ASTERACEAE	Black Jack	*		
Boscia albitrunca	CAPPARACEAE	Shepherd's tree		y	
Buxus macowanii	BUXACEAE	Cape Box			SA
Carissa bispinosa subsp. bispinosa	APOCYNACEAE	Num-num			
Colocasia esculenta	ARACEA	aMadumbe	*		
Conyza bonariensis	ASTERACEAE	Horseweed	*		
Croton megalobotrys	EUPHORBIACEAE				
Cynodon dactylon	POACEAE	Coach grass			
Dichrostachys cinerea	FABACEAE	Sickle Bush			
Diospyros mespiliformis	EBENACEAE	Jackal Berry			
Equisetum ramosissimum	EQUISETACEAE				
Eucalyptus camaldulensis	MYRTACEAE	River Red Gum	*		
Euclea divinorum	EBENACEAE				
Flueggea virosa	EUPHORBIACEAE	White-berry Bush			
Ischaemum fasciculatum	POACEAE	Hippo Grass			
Lantana camara	VERBENACEAE	Bird's Brandy	*		
Ludwigia adscendens subsp. diffusa	ONAGRACEAE				
Melia azedarach	MELIACEAE	Syringa	*		
Miscanthus junceus	POACEAE	Wireleaf daba grass			SnA
Nuxia oppositifolia	STILBACEAE				
Peltophorum africanum	FABACEAE				
Persicaria senegalensis	POLYGONACEAE	Silver snake root			
Phragmites mauritianus	POACEAE				
Potamogeton schweinfurthii	POTAMOGETONACEAE	Broad-leaved Pondweed			
Ranunculus multifidus	RANUNCULACEAE	Buttercup	*		
Stuckenia pectinatus	POTAMOGETONACEAE	Fennel-leaved Pondweed			
Tagetes minuta	ASTERACEAE	Khaki Weed	*		
Terminalia sericea	COMBRETACEAE	Silver clusterleaf			
Tithonia diversifolia	ASTERACEAE		*		
Trema orientalis	CANNABACEAE	Pigeonwood			
Vachellia karroo	FABACEAE	Sweet Thorn			
Vachellia tortilis	FABACEAE				
Xanthium strumarium	ASTERACEAE	Large Cocklebur	*		
Ziziphus mucronata	RHAMNACEAE	Buffalo thorn			

Table 6.6: VEGRAI level 4 score and category for 1_Lephalala

VEGRAI 4	1_Lephalala					08 August 2022
Zone	Calculated Rating	Weighted Rating	Confidence	Rank	Weight	Notes:
Aquatic zone	90.0	1.9	3.0	1.0	2.1	Weight = extent
Marginal zone	82.7	17.0	3.1	2.0	20.6	Weight = extent
Floodbench	68.9	42.6	2.8	3.0	61.9	Weight = extent
MCB	66.9	10.3	3.0	4.0	15.5	Weight = extent
VEGRAI (%)						71.9
VEGRAI Ecological Category						**C**
	Aquatic zone	Marginal zone	Floodbench	MCB		
VEGRAI %	90.0	82.7	68.9	66.9		
Ecological Category	A/B	B	C	C		

6.2.3.2 2_Rietfontein

Both river banks at 2_Rietfontein were assessed on the 6th of August 2022 from where the road leads to the channel up to the pool with large trees. The three zones assessed were the marginal zone, a floodbench and the MCB. The present and reference states for each are described in **Table 6.7** and the ratings of impacts in **Table 6.8.** There were 15 indigenous and 3 exotic species (**Table 6.9**). The PES score was 90.3%, an ecological category of A/B (**Table 6.10)**.

Table 6.7: Description of reference and present state for 2_Rietfontein

Zone	Description of reference state	Description of present state
 Marginal zone	The present state was the same as the reference state.	The marginal zone was well developed with wetland sedges and grasses being wetland habitats supported by permanent wetness from the upstream spring. These wetland plants existed in a confined channel subject to riparian flood dynamics. The dominant species were *Cyperus sexangularis, Juncus rigidus* and *Agrostis lachnantha* and there were some terrestrial creeping grasses such as *Cynodon dactylon*. Filamentous green algae were common in the slow-flowing, shallow channel.
 Floodbench		The floodbenches were alluvial and had the same species of grasses and sedges as the marginal zone with the following shrubs and trees: *Carissa bispinosa, Combretum imberbe, Euclea divinorum, Gymnosporia glaucophylla, Schotia brachypetala, Phoenix reclinata* and *Vachellia karroo.*
MCB		The MCB was alluvial and created a confined channel with the same woody species as the floodbench, and also of *Boscia albitrunca, Senegalia burkei* and *S.nigrescens.*

Table 6.8: Summary of impacts observed at 2_Rietfontein

Impacts	Intensity	Extent	Notes
Marginal zone			
Vegetation Removal	0	0	None
Alien Species Invasion	0	0	None
Terrestrial Species	0	0	None
Water Quantity	0	0	No impacts, permanent source from spring upstream.
Water Quality	0	0	None
Erosion	0	0	None
Floodbench			
Vegetation Removal	0	0	None
Alien Species Invasion	0.5	1	Minimal, only annual weed species.
Terrestrial Species	0.5	0.5	Not more than expected for the zone.
Water Quantity	0	0	None
Water Quality	0	0	None
Erosion	0	0	None
MCB			
Vegetation Removal	0.5	0.5	Minimal, road access to river and hunting sites.
Alien Species Invasion	0.5	1	Minimal, mainly alien annual weed species.
Terrestrial Species	0	0	Not more or less than expected.
Water Quantity	0	0	None
Water Quality	0	0	None
Erosion	0	0	None

Table 6.9: List of plant species observed at 2_Rietfontein (Ex. Exotic)

Species	Family	Common Name/s	Ex.
Agrostis lachnantha var. lachnantha	POACEAE	Bent grass	
Argemone mexicana	PAPAVERACEAE	Yellow Mexican Poppy	*
Bidens pilosa	ASTERACEAE	Black Jack	*
Boscia albitrunca	CAPPARACEAE	Shepherd's tree	
Carissa bispinosa subsp. bispinosa	APOCYNACEAE	Num-num	
Combretum imberbe	COMBRETACEAE	Leadwood	
Conyza bonariensis	ASTERACEAE	Horseweed	*
Cynodon dactylon	POACEAE	Coach grass	
Cyperus sexangularis	CYPERACEAE		
Euclea divinorum	EBENACEAE		
Grewia bicolor	MALVACEAE		
Gymnosporia glaucophylla	CELASTRACEAE		
Juncus rigidus	JUNCACEAE		
Phoenix reclinata	ARECACEAE	Wild date palm	
Schotia brachypetala	FABACEAE	Weeping boerbean	
Senegalia burkei	FABACEAE		
Senegalia nigrescens	FABACEAE		
Vachellia karroo	FABACEAE	Sweet Thorn	

Table 6.10: VEGRAI level 4 score and category for 2_Rietfontein

VEGRAI 4	2_Rietfontein					06 August 2022
Zone	Calculated Rating	Weighted Rating	Confidence	Rank	Weight	Notes:
Marginal zone	95.0	29.7	3.5	1.0	31.3	Weight = extent
Floodbench	88.0	27.5	3.6	2.0	31.3	Weight = extent
MCB	88.5	33.2	3.4	3.0	37.5	Weight = extent
VEGRAI (%)						90.3
VEGRAI Ecological Category						**A/B**
	Marginal zone	Floodbench	MCB			
VEGRAI %	95.0	88.0	88.5			
Ecological Category	A	A/B	A/B			

6.2.3.3 3_Olifantspruit

The marginal zone and MCB on both banks of 3_Olifantspruit were assessed on the 8th of August 2022 from the bridge downstream for 130 m. The present and reference states for each sub-zone are described in **Table 6.11** and the ratings of impacts in **Table 6.12.** There were 24 indigenous and 11 exotic species (**Table 6.13**). The PES score was 57.3%, an ecological category of D (**Table 6.14)**.

Table 6.11: Description of reference and present state for 3_Olifantspruit

Zone	Description of reference state	Description of present state
 Marginal zone	Historically the channel was more open with less woody vegetation, less shading and more non-woody plants.	The marginal zone was confined with non-woody plants, some shrubs and overhanging trees, and some patches with little or no vegetation, and some reeds. The main plants were *Phragmites australis, Juncus dregeanus* and *Juncus oxycarpus*. The main shade tree was the exotic *Melia azedarch.*
 MCB	The MCB was expected to be less woody with more open and grasses areas. There should be more trees like *Combretum erythrophyllum*.	The MCB comprised woody trees and shrubs, but these were mostly exotics. Some parts of the bank were open with grasses and exotric shrubs. The main species were *Combretum erythrophyllum, Diospyros lycioides* and *Vachellia karroo*, and the exotics *Melia azedarach, Morus alba, Lantana camara* and *Sesbania punicea.*

Table 6.12: Summary of impacts observed at 3_Olifantspruit

Impacts	Intensity	Extent	Notes
Marginal zone			
Vegetation Removal	1	1	Access paths and areas around bridge cleared.
Alien Species Invasion	2	2	*Melia azedarach* saplings but also shading from other tall alien trees.
Terrestrial Species	1	1	Higher than expected, localised at access points.
Water Quantity	0.5	5	A few small farm dams upstream.
Water Quality	0	5	None
Erosion	1	1	Localised at access points.
MCB			
Vegetation Removal	3	4	Clearing has been done for access and security (farmers pers com), and wood removal.
Alien Species Invasion	3	5	*Melia azedarach, Morus alba* and *Lantana camara* were common and abundant, as were exotic annual weeds.
Terrestrial Species	2	3	Higher than expected.
Water Quantity	0	5	None
Water Quality	0	5	None
Erosion	2	1	Localised at access points and along road with sediments going into the zone.

Table 6.13: List of plant species observed at 3_Olifantspruit (Ex = exotic, P = protected, En. = endemic)

Species	Family	Common Name/s	Ex.	P	En.
Argemone mexicana	PAPAVERACEAE	Yellow Mexican Poppy	*		
Bidens pilosa	ASTERACEAE	Black Jack	*		
Celtis africana	CELTIDACEAE	White Stinkwood			
Combretum apiculatum	COMBRETACEAE				
Combretum erythrophyllum	COMBRETACEAE	River bushwillow			SnA
Combretum microphyllum	COMBRETACEAE				
Conyza bonariensis	ASTERACEAE	Horseweed	*		
Dichrostachys cinerea	FABACEAE	Sickle Bush			
Diospyros lycioides subsp. lycioides	EBENACEAE	Bluebush			
Equisetum ramosissimum	EQUISETACEAE				
Euclea divinorum	EBENACEAE				
Gomphocarpus fruticosus	APOCYNACEAE	Milkweed			
Grewia villosa	MALVACEAE	Mallow raisin			
Juncus dregeanus subsp. dregeanus	JUNCACEAE				
Juncus oxycarpus	JUNCACEAE				
Lantana camara	VERBENACEAE	Bird's Brandy	*		
Melia azedarach	MELIACEAE	Syringa	*		
Morus alba var. alba	MORACEAE	White Mulberry	*		
Panicum maximum	POACEAE	Guinea Grass			
Peltophorum africanum	FABACEAE				
Phragmites australis	POACEAE	Common Reed			
Prunus persica	ROSACEAE	Peach tree	*		
Ricinus communis	EUPHORBIACEAE	Cateroil Bush	*		
Salix mucronata subsp. woodii	SALICACEAE				
Searsia lancea	ANACARDIACEAE				
Searsia lepidictya	ANACARDIACEAE				
Senna didymobotrya	FABACEAE	Peanut butter cassia	*		
Sesbania punicea	FABACEAE	Red Sesbania	*		
Setaria megaphylla	POACEAE	Broad-leaved bristle grass			

Species	Family	Common Name/s	Ex.	P	En.
Sida dregei	MALVACEAE				
Tagetes minuta	ASTERACEAE	Khaki Weed	*		
Terminalia sericea	COMBRETACEAE	Silver clusterleaf			
Themeda triandra	POACEAE	Red Grass			
Vachellia karroo	FABACEAE	Sweet Thorn			
Ziziphus mucronata	RHAMNACEAE	Buffalo thorn			

Table 6.14: VEGRAI level 4 score and category for 3_Olifantspruit

VEGRAI 4	3_Olifantspruit					08 August 2022
Zone	Calculated Rating	Weighted Rating	Confidence	Rank	Weight	Notes:
Marginal zone	67.5	13.5	3.0	1.0	20.0	Weight = extent
MCB	54.8	43.8	3.1	2.0	80.0	Weight = extent
VEGRAI (%)						57.3
VEGRAI Ecological Category						**D**
	Marginal zone	MCB				
VEGRAI %	67.5	54.8				
Ecological Category	C	D				

6.2.3.4 4_Mogalakwena1

The marginal zone, floodbench and MCB on both banks of 4_Mogalakwena were assessed on the 7th of August 2022 from the confluence downstream for 130 m. The present and reference states for each zone are described in **Table 6.15** and the ratings of impacts in **Table 6.16**. There were 16 indigenous and 10 alien species (**Table 6.17)**. The PES score was 61.6%, an ecological category of **C/D** (**Table 6.18**).

Table 6.15: Description of reference and present state for 4_Mogalakwena1

Zone	Description of reference state	Description of present state
 Marginal zone	This river should be narrower with more reeds and fewer woody trees and shrubs.	The marginal zone was narrow and confined with reeds (*P. mauritianus*), sedges and *Juncus lomatophyllus*. There were some woody overhanging plants along the pools and the disturbed sandy areas had exotic weeds like *Xanthium strumarium*.
 Floodbench	The floodbench would have comprised reeds in dense and less dense stands.	The floodbench had open areas and those where reeds and the shrub *Flugea virosa* were growing with the grasses *Agrostis lachnantha, C. dactylon.* Grazing, trampling pressure and disturbance was high. The terrestrial bush *Dichrostachys cinerea* was encroaching into the riparian area and the exotic tree *Melia azedarch* was present.
 MCB	The MCB should comprise a clear line of dense woody trees and shrubs.	The MBC had a low density of shrubs and trees,due to high grazing and trampling pressure, removal for access and some erosion along access routes. The main species were *Vachellia karroo, Combretum erythrophyllum, Gymnosporia senegalensis* and *Ziziphus mucronata.* The exotic tree *Melia azedarch* was present.

Table 6.16: Summary of impacts observed at 4_Mogalakwena1

Impacts	Intensity	Extent	Notes
Marginal zone			
Vegetation Removal	2	5	Removal mainly due to grazing, trampling pressure and clearing for access roads and paths.
Alien Species Invasion	2	1	Localised erosion of denuded areas was evident, and these disturbed areas also supported alien weeds, notably *Xanthium strumarium*.
Terrestrial Species	0	0	None
Water Quantity	3	5	The Doorndraai dam was upstream on the Sterk River, and the Nyl Dam on the Nyl River, and will alter flow. There are also return flows from agricultural irrigation and WWTW.
Water Quality	2	5	Ga-Pila Sterkwater WWTW was upstream, and other WWTWs are at the town of Mokopane. Livestock were watered in the river Potentially and there were a few low-level crossings.
Erosion	1	2	Undercut banks around pools, localised erosion at access and livestock watering points.
Floodbench			
Vegetation Removal	2.5	5	Removal mainly due to grazing, trampling pressure and clearing for access roads and paths.
Alien Species Invasion	1.5	2	Aliens comprised mostly annual weeds but also included *Melia azedarch.*
Terrestrial Species	3	2.5	Dichrostachys cinerea was enchroaching.
Water Quantity	1.5	5	The Doorndraai dam was upstream on the Sterk River, and the Nyl Dam on the Nyl River, and will alter flow.
Water Quality	0	0	None
Erosion	1	2	Localised erosion at access and livestock watering points.
MCB			
Vegetation Removal	1.5	3	Livestock grazing and trampling pressure, access roads and wood removal.
Alien Species Invasion	1	2	Alien annual weed species were common in disturbed areas and *Melia azedarch* also occurred.
Terrestrial Species	0.5	1	Close to expectation
Water Quantity	0	0	None
Water Quality	0	0	None
Erosion	2	2	Associated with road access areas along banks or to the river.

Table 6.17: List of plant species observed at 4_Mogalakwena1 (Ex. = exotic, P = protected, En. = endemic, SnA = southern Africa)

Species	Family	Common Name/s	Ex.	P	En.
Ageratum houstonianum	ASTERACEAE	Bluemink	*		
Agrostis lachnantha var. lachnantha	POACEAE	Bent grass			
Argemone mexicana	PAPAVERACEAE	Yellow Mexican Poppy	*		
Bidens pilosa	ASTERACEAE	Black Jack	*		
Combretum erythrophyllum	COMBRETACEAE	River bushwillow			SnA
Conyza bonariensis	ASTERACEAE	Horseweed	*		
Cynodon dactylon	POACEAE	Coach grass			
Dichrostachys cinerea	FABACEAE	Sickle Bush			
Equisetum ramosissimum	EQUISETACEAE				
Euclea divinorum	EBENACEAE				
Flueggea virosa	EUPHORBIACEAE	White-berry Bush			
Gymnosporia senegalensis	CELASTRACEAE	Red spike-thorn			
Juncus lomatophyllus	JUNCACEAE				
Melia azedarach	MELIACEAE	Syringa	*		
Persicaria senegalensis forma senegalensis	POLYGONACEAE	Silver snake root			
Phragmites mauritianus	POACEAE				
Pycreus betschuanus	CYPERACEAE				
Searsia lancea	ANACARDIACEAE				
Senna didymobotrya	FABACEAE	Peanut butter cassia	*		
Sida dregei	MALVACEAE				
Sporobolus ioclados	POACEAE	Pan Dropseed			
Tagetes minuta	ASTERACEAE	Khaki Weed	*		
Vachellia karroo	FABACEAE	Sweet Thorn			
Vachellia tortilis	FABACEAE				
Xanthium strumarium	ASTERACEAE	Large Cocklebur	*		
Ziziphus mucronata	RHAMNACEAE	Buffalo thorn			

Table 6.18: VEGRAI level 4 score and category for 4_Mogalakwena1

VEGRAI 4	4_Mogalakwena					07 August 2022
Zone	Calculated Rating	Weighted Rating	Confidence	Rank	Weight	Notes:
Marginal zone	57.7	13.3	3.0	1.0	23.1	Weight = extent
Floodbench	57.8	26.7	3.1	2.0	46.2	Weight = extent
MCB	70.2	21.6	3.3	3.0	30.8	Weight = extent
VEGRAI (%)						61.6
VEGRAI Ecological Category						**C/D**
	Marginal zone	Floodbench	MCB			
VEGRAI %	57.7	57.8	70.2			
Ecological Category	C/D	C/D	C			

6.2.3.5 5_Mogalakwena2

The marginal zone, floodbench and MCB on both banks of 5_Mogalakwena were assessed on the 7th of August 2022 over a distance of 140 m. The present and reference states for each zone are described in **Table 6.19** and the ratings of impacts in **Table 6.20**. There were 22 indigenous and 9 exotic plants (**Table 6.21**). The PES score was 70.5%, an ecological category of C (**Table 6.22**).

Table 6.19: Description of reference and present state for 5_Mogalakwena2

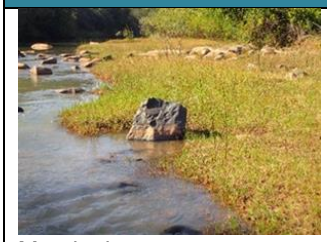
Zone	Description of reference state	Description of present state
 Marginal zone	The marginal zone should be a narrow channel not dominated by woody vegetation, but rather with alluvial sand bars with non-woody vegetation such as reeds.	The marginal zone comprised Leafy juncus (*Juncus lomatophyllus*), erect sedges (*Cyperus digitatus*), hydrophilic grasses (*Ischaemum fasciculatum*) and two trees, indigenous *Salix mucronata* and exotic *Sesbanea punicea*. There were some trees overhanging the pools, otherwise the zone looked like grazed lawn. There were no reeds.
 Floodbench	The floodbench should comprise reeds and *Salix mucronata* trees, or open area of sand/gravel bars.	The floodbench was a mixture of sedges (*Cyperus digitatus*) and shubs (*Gomphocarpus fruticosus*) Grazing and trampling pressure were high and the exotic tree *Sesbanea punicea* was present with some other exotic weeds.
 MCB	The MCB should form a clear and dense line of woody trees and shrubs.	The left bank was short and steep and the right bank more gently sloping, both had dense trees and shrubs. Access paths (livestock and people) had eroded to form gullies and grazing pressure was high. The main plants were indigenous *Vachellia karroo, V. erioloba, Gymnosporia senegalensis, P. violacea, Faidherbia albida, Schotia brachypetala, Dichrostachys cinerea* and *Ziziphus mucronata.* There were a few exotic annual weeds and no exotic trees.

Table 6.20: Summary of impacts observed at 5_Mogalakwena2

Impacts	Intensity	Extent	Notes
Marginal zone			
Vegetation Removal	3	4	High livestock grazing pressure, especially on sedges.
Alien Species Invasion	1	1	Low density but *Sesbanea punicea* seedlings were present.
Terrestrial Species	0	0	None
Water Quantity	3.5	5	Glen Alpine dam was upstream and did alter flow patterns.
Water Quality	0.5	5	Low probability
Erosion	0	0	None
Floodbench and channel			
Vegetation Removal	1	3	Removal mainly due to grazing, trampling pressure and clearing for access roads and paths.
Alien Species Invasion	2	2.5	Aliens comprised annual weeds and *Sesbanea punicea*.
Terrestrial Species	2	3	Higher cover and abundance than expected, likely due to flow regulation and flood peak reduction.
Water Quantity	3	5	Glen Alpine dam was upstream and did alter flow patterns.
Water Quality	0	0	None
Erosion	1	1	Localised erosion at access and livestock watering points.
MCB			
Vegetation Removal	2	2	Livestock grazing, trampling pressure, access roads and wood removal.
Alien Species Invasion	0	0	None
Terrestrial Species	1	1	Close to expectation.
Water Quantity	0	0	None
Water Quality	0	0	None
Erosion	3	4	Eroded banks and access gullies, especially from trampling and access points.

Table 6.21: List of plant species observed at 5_Mogalakwena2 (Ex. = exotic, P = protected, y = yes, En. = endemic)

Species	Family	Common Name/s	Ex.	P	En.
Agrostis lachnantha var. lachnantha	POACEAE	Bent grass			
Argemone mexicana	PAPAVERACEAE	Yellow Mexican Poppy	*		
Bidens pilosa	ASTERACEAE	Black Jack	*		
Combretum imberbe	COMBRETACEAE	Leadwood		y	
Conyza bonariensis	ASTERACEAE	Horseweed	*		
Cryptostegia grandiflora	APOCYNACEAE	Rubber vine	*		
Cynodon dactylon	POACEAE	Coach grass			
Cyperus digitatus subsp. auricomus	CYPERACEAE				
Dichrostachys cinerea	FABACEAE	Sickle Bush			
Faidherbia albida	FABACEAE	Anna Boom			
Flueggea virosa	EUPHORBIACEAE	White-berry Bush			
Gardenia volkensii var volkensii	RUBIACEAE	Bushveld Gardenia			
Gomphocarpus fruticosus	APOCYNACEAE	Milkweed			
Gymnosporia senegalensis	CELASTRACEAE	Red spike-thorn			
Ischaemum fasciculatum	POACEAE	Hippo Grass			
Juncus lomatophyllus	JUNCACEAE				
Lantana camara	VERBENACEAE	Bird's Brandy	*		
Opuntia ficus-indica	CACTACEAE		*		
Philenoptera violacea	FABACEAE	Apple-leaf		y	
Pycreus betschuanus	CYPERACEAE				
Ricinus communis	EUPHORBIACEAE	Cateroil Bush	*		
Salix mucronata subsp. woodii	SALICACEAE				

Species	Family	Common Name/s	Ex.	P	En.
Schotia brachypetala	FABACEAE	Weeping boerbean			y
Senegalia schweinfurthii var. schweinfurthii	FABACEAE	River climbing thorn			
Sesbania punicea	FABACEAE	Red Sesbania	*		
Sida dregei	MALVACEAE				
Tagetes minuta	ASTERACEAE	Khaki Weed	*		
Vachellia erioloba	FABACEAE	Camel thorn		y	
Vachellia karroo	FABACEAE	Sweet Thorn			
Vachellia tortilis	FABACEAE				
Ziziphus mucronata	RHAMNACEAE	Buffalo thorn			

Table 6.22: VEGRAI level 4 score and category for 5_Mogalakwena2

VEGRAI 4	5_Mogalakwena					07 August 2022
Zone	Calculated Rating	Weighted Rating	Confidence	Rank	Weight	Notes:
Marginal zone	60.3	14.2	3.0	1.0	23.5	Weight = extent
Floodbench	57.1	10.1	3.1	2.0	17.6	Weight = extent
MCB	78.6	46.2	3.3	3.0	58.8	Weight = extent
VEGRAI (%)						70.5
VEGRAI Ecological Category						**C**
	Marginal zone	Floodbench	MCB			
VEGRAI %	60.3	57.1	78.6			
Ecological Category	C/D	D	B/C			

6.2.3.6 6_Kolope

The ephemeral channel, floodbench and MCB were assessed on both banks of 6_Kolope on the 7th August 2022 from the fence line for about 150m upstream to the large Nyala Berry. The present and reference states for each zone are described in **Table 6.23** and the ratings of impacts in

Table 6.24**.** There were 11 indigenous and 4 alien plants (**Table 6.25**). The PES score was 73.1%, an ecological category of **C** (**Table 6.26)**.

Table 6.23: Description of reference and present state for 6_Kolope

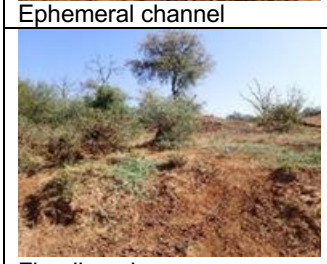
Zone	Description of reference state	Description of present state
 Ephemeral channel	The channel should have more woody trees and shrubs.	There were mainly exotic annual weeds (*Bidens pilosa, Xanthium strumarium*), ground creeping forbs and some tufted grasses (*Setaria incrassata*).
 Floodbench	The floodbench should have woody shrubs or short trees including Combretum microphyllum, Flueggea virosa, Lycium cinereum, Salvadora australis and Vachellia tortilis.	The floodbench had either no plants or comprised a mix of forbs, grasses and short shrubs (*Flueggea virosa, Croton megalobotrys, Vachellia tortilis)*. Trampling by elephants was high and the zone was eroded. Exotic annual weeds were present (*Bidens pilosa, Xanthium strumarium* and *Tagetes minuta*).
 MCB	The MCB should be densely wooded with taller trees and shrubs including Combretum imberbe, Croton megalobotrys Dichrostachys cinerea, Philenoptera violacea, Vachellia tortilis and Xanthocercis zambesiaca.	The MCB comprised woody trees and shrubs but the impact by elephant and other megaherbivores was clear with much denudation, high trampling pressure, extensive plant death/damage and eroding trampled banks. Hence much of the MCB was unvegetated. Common species included *Combretum imberbe, Combretum microphyllum, Croton megalobotrys, Dichrostachys cinerea, Philenoptera violacea, Salvadora australis, Vachellia tortilis* and some *Xanthocercis zambesiaca*.

Table 6.24: Summary of impacts observed at 6_Kolope

Impacts	Intensity	Extent	Notes
Ephemeral channel			
Vegetation Removal	0	0	Removal was high but because by wildlife in a national park the impacts was not scored as an impact.
Alien Species Invasion	1	2	Limited to annual weeds species.
Terrestrial Species	0	0	None
Water Quantity	1	5	A few small farm dams upstream.
Water Quality	0	5	None
Erosion	2	2	Denuded elephant paths with some incision.
Floodbench			
Vegetation Removal	0	0	Removal was high but because by wildlife in a national park the impacts was not scored as an impact.
Alien Species Invasion	1	1	Limited to annual weeds species.
Terrestrial Species	0	0	None
Water Quantity	0.5	5	A few small farm dams upstream.
Water Quality	0	5	None
Erosion	3	3	Denuded elephant paths have eroded with rainfall and floods.

Impacts	Intensity	Extent	Notes
MCB			
Vegetation Removal	0	0	Removal was high but because by wildlife in a national park the impacts was not scored as an impact.
Alien Species Invasion	1	1	Limited to annual weeds species.
Terrestrial Species	0	0	None
Water Quantity	0	5	None
Water Quality	0	5	None
Erosion	3	3	Denuded elephant paths have eroded with rainfall and floods.

Table 6.25: List of plant species observed at 6_Kolope (Ex. = exotic, P = protected, y = yes, En. = endemic)

Species	Family	Common Name/s	Ex.	P	En.
Argemone mexicana	PAPAVERACEAE	Yellow Mexican Poppy	*		
Bidens pilosa	ASTERACEAE	Black Jack	*		
Combretum imberbe	COMBRETACEAE	Leadwood		y	
Combretum microphyllum	COMBRETACEAE				
Croton megalobotrys	EUPHORBIACEAE				
Dichrostachys cinerea	FABACEAE	Sickle Bush			
Flueggea virosa	EUPHORBIACEAE	White-berry Bush			
Lycium cinereum	SOLANACEAE				
Philenoptera violacea	FABACEAE	Apple-leaf		y	
Salvadora australis	SALVADORACEAE	Narrow-leaved mustard tree			
Setaria incrassata	POACEAE	Vlei Bristle Grass			
Tagetes minuta	ASTERACEAE	Khaki Weed	*		
Vachellia tortilis	FABACEAE				
Xanthium strumarium	ASTERACEAE	Large Cocklebur	*		
Xanthocercis zambesiaca	FABACEAE	Nyala tree			

Table 6.26: VEGRAI level 4 score and category for 6_Kolope

VEGRAI 4	6_KOLOPE					07 August 2022
Zone	Calculated Rating	Weighted Rating	Confidence	Rank	Weight	Notes:
Ephemeral channel	80.0	17.4	3.0	1.0	21.7	Weight = extent
Flood bench	71.1	9.3	3.1	2.0	13.0	Weight = extent
MCB	71.2	46.4	3.3	3.0	65.2	Weight = extent
VEGRAI (%)						73.1
VEGRAI Ecological Category						**C**
	Ephemeral channel	Flood bench	MCB			
VEGRAI % (Zone)	80.0	71.1	71.2			
Ecological Category (Zone)	B/C	C	C			

6.2.3.7 7_Sand

The channel bed, floodbench and MCB on both banks of 7_Sand were assessed on the 1st of August 2022 from the bridge for a distance of 150 m downstream. The present and reference states for each zone are described in **Table 6.27** and the ratings of impacts in **Table 6.28**. There were 15 indigenous and 9 exotic plants (**Table 6.29**). The PES score was 69.7%, an ecological category of C (**Table 6.30**).

Table 6.27: Description of reference and present state for 7_Sand

Zone	Description of reference state	Description of present state
 Channel bed	The Sand River was non-perennial and should be an open sandy channel with little woody and non-woody vegetation.	There were few plants, the main species were exotic annual weeds, for example *Xanthium strumarium*, and terrestrial grasses such as *Cynodon dactylon*.
 Floodbench	The floodbench should comprise mostly non-woody grasses with some woody shrubs and trees.	The floodbench comprised grasses such as *C. dactylon, Sporobolus ioclados* and *Pennisetum macrourum*) with the exotic annual weeds *X. strumarium* and *Tagetes minuta*. There were a few indigenous tree saplings of *Vachellia karroo* but no adults.
 MCB	The MCB should comprise a dense clear riparian area of woody trees and shrubs.	The MCB was dominated by tall trees and shrubs with a clear and dense treeline and some areas of open grass. Grazing and browsing were low. The main plants were grasses *Sporobolus ioclados* and *Panicum maximum,* and trees *Vachellia karroo, V. tortilis, Gymnosporia senegalensis, Carissa bispinosa, Dichrostachys cinerea* and *Ziziphus mucronata*. The exotic shrubs *Nicotiana glaucea, Opuntia ficus-indica* and tree *Melia azedarach* were present at low density.

Table 6.28: Summary of impacts observed at 7_Sand

Impacts	Intensity	Extent	Notes
Channel bed			
Vegetation Removal	0	0	None
Alien Species Invasion	2	1	Annual weed species and *Nicotiana glaucea.*
Terrestrial Species	0	0	None
Water Quantity	1	5	The site is downstream of Polokwane and there was of groundwater abstraction for agriculture.
Water Quality	0.5	5	Low probability
Erosion	0	0	None
Floodbench			
Vegetation Removal	0	0	None
Alien Species Invasion	2	3	Annual weed species and also *Nicotiana glaucea.*
Terrestrial Species	1	2	Higher cover and abundance than expected.
Water Quantity	0	0	None
Water Quality	0	0	None

Impacts	Intensity	Extent	Notes
Erosion	0	0	None
MCB			
Vegetation Removal	1	1	Grazing appears to be absent, but some access paths and roads.
Alien Species Invasion	2	2	Annual weed species and also Nicotiana glaucea and Eucalyptus camaldulensis.
Terrestrial Species	1	1	Close to expectation
Water Quantity	0	0	None
Water Quality	0	0	None
Erosion	0	0	None

Table 6.29: List of plant species observed at 7_Sand (Ex. = exotic, P = protected, En. = endemic, SnA = southern Africa)

Species	Family	Common Name/s	Ex.	P	En.
Argemone mexicana	PAPAVERACEAE	Yellow Mexican Poppy	*		
Bidens pilosa	ASTERACEAE	Black Jack	*		
Carissa bispinosa subsp. bispinosa	APOCYNACEAE	Num-num			
Combretum erythrophyllum	COMBRETACEAE	River bushwillow			SnA
Conyza bonariensis	ASTERACEAE	Horseweed	*		
Cynodon dactylon	POACEAE	Coach grass			
Dichrostachys cinerea	FABACEAE	Sickle Bush			
Eucalyptus camaldulensis	MYRTACEAE	River Red Gum	*		
Gomphocarpus fruticosus	APOCYNACEAE	Milkweed			
Gymnosporia senegalensis	CELASTRACEAE	Red spike-thorn			
Leonotis ocymifolia	LAMIACEAE				
Melia azedarach	MELIACEAE	Syringa	*		
Nicotiana glaucea	SOLANACEAE		*		
Opuntia ficus-indica	CACTACEAE		*		
Panicum coloratum var. coloratum	POACEAE	White Buffalo Grass			
Panicum maximum	POACEAE	Guinea Grass			
Pennisetum macrourum	POCEAE				
Senegalia mellifera subsp. detinens	FABACEAE				
Sporobolus ioclados	POACEAE	Pan Dropseed			
Tagetes minuta	ASTERACEAE	Khaki Weed	*		
Vachellia karroo	FABACEAE	Sweet Thorn			
Vachellia tortilis	FABACEAE				
Xanthium strumarium	ASTERACEAE	Large Cocklebur	*		
Ziziphus mucronata	RHAMNACEAE	Buffalo thorn			

Table 6.30: VEGRAI level 4 score and category for 7_Sand

VEGRAI 4	7_Sand					01 August 2022
Zone	Calculated Rating	Weighted Rating	Confidence	Rank	Weight	Notes:
Channel bed	70.0	22.1	3.0	1.0	31.6	Weight = extent
Floodbench	55.0	14.5	3.1	2.0	26.3	Weight = extent
MCB	78.7	33.1	3.3	3.0	42.1	Weight = extent
VEGRAI (%)						69.7
VEGRAI Ecological Category						**C**
	Channel bed	Floodbench	MCB			
VEGRAI %	70.0	55.0	78.7			
Ecological Category	C	D	B/C			

6.2.3.8 8_Nzhelele

The marginal zone, floodbench and MCB on both banks of 8_Nzhelele were assessed on the 5th of August 2022 from the large Jackal Berry downstream for a distance of 200m. The present and reference states for each zone are described in **Table 6.31** and the ratings of impacts in Table 6.32**.** There were 25 indigenous and 6 alien plants (**Table 6.33**). The PES score was 77.8%, an ecological category of **B/C** (**Table 6.34**).

Table 6.31: Description of reference and present state for 8_Nzhelele

Zone	Description of reference state	Description of present state
 Marginal zone	The marginal zone should have reeds and some woody shrubs such as *Pluchea bojeri* and *Gomphostigma virgatum* and trees like *Breonadia salicina*.	The marginal zone comprised unvegetated gravel and cobble bars with some sparse sedges, *Juncus oxycarpus and Cyperus sexangularis*. There were some reeds (*Phragmites mauritianus*) on the left bank, but most of the plants were woody shrubs (mainly *Pluchea bojeri*). There were no *Gomphostigma virgatum* or *Breonadia salicina*.
 Floodbench	The floodbenches should have few plants and less flow sensitive species such as *C. sexangularis, P. mauritianus* or *Pluchea bojeri.* There should be a mix of woody and non-woody plants.	Thefloodbenches comprised a high density of shrubs (mainly *Pluchea bojeri*) with a few sedges here and there. There were some trees, like *Philonoptera violacea* and *Vachellia gerarrdii* and non-woody sedges *Stipagrostis uniplumis* and *Cyperus sexangularis*. Grazing and trampling pressure were high.
 MCB	The MCB should have a dense and clear line of riparian trees and shrubs and a well-vegetated understorey.	The MCB comprised shrubs and trees, some areas with some high density patches, most areas were open to sparse. Some removal and clearing for cultivation was evident. Indigenous species included *Diospyros mespiliformis, Dichrostachys cinerea, Euclea divinorum, Gymnosporia senegalensis, Vachellia karroo, Schotia brachypetala, Xanthocercis zambesiaca* and *Ziziphus mucronata. X. zambesiaca* was recruiting juveniles of different sizes and there were few exotic annual weeds. The exotic cactus*Opuntia ficus-indica* and tree *Senna didymobotrya* were present.

Table 6.32: Summary of impacts observed at 8_Nzhelele

Impacts	Intensity	Extent	Notes
Marginal/ Lower zone			
Vegetation Removal	0	0	None
Alien Species Invasion	0	0	None
Terrestrial Species	0	0	None
Water Quantity	2	5	The Nzhelele dam on the Nzhelele River upstream of the site caused flow reductions and reduced flood peaks. There were also off-channel dams filled by abstraction and used to irrigate citrus farming.
Water Quality	1.5	5	Potentially affected by citrus farming and irrigation return flows upstream and close to the site.
Erosion	0	0	None
Floodbench			
Vegetation Removal	2	2	Appeared to be old fields on some alluvial benches, that were now fallow.
Alien Species Invasion	1	1	Low, limited to annual alien weed species.
Terrestrial Species	0.5	1	Close to expectation.
Water Quantity	1.5	5	The Nzhelele dam on the Nzhelele River upstream of the site caused flow reductions and reduced flood peaks. There were also off-channel dams filled by abstraction and used to irrigate citrus farming.
Water Quality	1	5	Potentially affected by citrus farming and irrigation return flows upstream and close to the site.
Erosion	0	0	None
MCB			
Vegetation Removal	2	2	Appeared to be old fields on some alluvial benches, that were now fallow.
Alien Species Invasion	1	1	Low, limited to annual alien weed species with some prickly pear.
Terrestrial Species	0.5	1	Close to expectation.
Water Quantity	0	0	None
Water Quality	0	0	None
Erosion	2	1	Associated with road access areas along banks or to the river.

Table 6.33: List of plant species observed at 8_Nzhelele (Ex. = exotic)

Species	Family	Common Name/s	Ex.
Argemone mexicana	PAPAVERACEAE	Yellow Mexican Poppy	*
Bidens pilosa	ASTERACEAE	Black Jack	*
Colophospermum mopane	FABACEAE	Mopane	
Combretum imberbe	COMBRETACEAE	Leadwood	
Conyza bonariensis	ASTERACEAE	Horseweed	*
Cynodon dactylon	POACEAE	Coach grass	
Cyperus sexangularis	CYPERACEAE		
Dichrostachys cinerea	FABACEAE	Sickle Bush	
Digitaria eriantha	POACEAE	Finger Grass	
Diospyros mespiliformis	EBENACEAE	Jackal Berry	
Ficus sycomorus	MORACEAE	Sycomore Fig	
Flueggea virosa	EUPHORBIACEAE	White-berry Bush	
Grewia bicolor	MALVACEAE		
Grewia flavescens	MALVACEAE	Sandpaper Raisin	
Gymnosporia senegalensis	CELASTRACEAE	Red spike-thorn	
Juncus oxycarpus	JUNCACEAE		

Species	Family	Common Name/s	Ex.
Opuntia ficus-indica	CACTACEAE		*
Philenoptera violacea	FABACEAE	Apple-leaf	
Phragmites mauritianus	POACEAE		
Pluchea bojeri	ASTERACEAE	Bushveld Camphorweed	
Schotia brachypetala	FABACEAE	Weeping boerbean	
Senegalia burkei	FABACEAE		
Senna didymobotrya	FABACEAE	Peanut butter cassia	*
Sida dregei	MALVACEAE		
Stipagrostis uniplumis	POACEAE	Silky Bushman Grass	
Tagetes minuta	ASTERACEAE	Khaki Weed	*
Vachellia gerrardii	FABACEAE	Gerrard's Acacia	
Vachellia karroo	FABACEAE	Sweet Thorn	
Vachellia tortilis	FABACEAE		
Xanthocercis zambesiaca	FABACEAE	Nyala tree	
Ziziphus mucronata	RHAMNACEAE	Buffalo thorn	

Table 6.34: VEGRAI level 4 score and category for 8_Nzhelele

VEGRAI 4	8_Nzhelele					05 August 2022
Zone	Calculated Rating	Weighted Rating	Confidence	Rank	Weight	Notes:
Marginal zone	77.4	19.8	3.2	1.0	25.6	Weight = extent
Floodbench	75.6	33.4	3.1	2.0	44.2	Weight = extent
MCB	81.4	24.6	3.3	3.0	30.2	Weight = extent
VEGRAI (%)						77.8
VEGRAI Ecological Category						**B/C**
	Marginal zone	Floodbench	MCB			
VEGRAI %	77.4	75.6	81.4			
Ecological Category	B/C	C	B/C			

6.2.3.9 9_Ṅwaneḍi

The marginal zone, floodbench and MCB on both banks of 9_Ṅwaneḍi were assessed on the 5th of August 2022 from the low-level road crossing for 180m downstream to the bend. The present and reference states for each zone are described in **Table 6.35** and the ratings of impacts in **Table 6.36**. There were 21 indigenous and 8 alien plants (**Table 6.37)**. The PES score was 76.3%, an ecological category of **C** (**Table 6.38)**

Table 6.35: Description of reference and present state for 9_Ṅwaneḍi

Zone	Description of reference state	Description of present state
 Marginal zone	The marginal zone should be dominated by tall and dense woody vegetation and because the channel is narrow and confined the marginal zone was expected to comprise shade-loving species in low densities and opportunistic species in sunspots.	The marginal zone comprised herbaceous plants (Commelina diffusa, Ranunculus multifidus and Persicaria lapathifolia) in the sunspots and trees Ficus sycomorus, Buxus macowanii and Breonadia salicina in the shaded areas.
 Floodbench	The floodbench should comprise dense tall trees and shrubs, forming a clear riparian corridor along the narrow and confined channel, with little or no understorey because of the shade.	The floodbench comprised a high density of tall trees and shrubs, with little to no understorey vegetation, leading to a highly dense clear riparian area of trees Ficus sycomorus, Breonaria salicina, Combretum erythrophyllum and Faidherbia albida.
 MCB	The MCB should comprise dense tall trees and shrubs, forming a clear riparian corridor along the narrow and confined channel, with little or no understorey because of the shade.	The MCB had a high density of short and tall shrubs and trees with no understorey vegetation. Indigenous species included Ekebergia capensis, Schotia brachypetala, Xanthocercis zambesiaca, Faidherbia albida, Mimusops zeyheri, Vachellia karroo and Ziziphus mucronata. Exotic annuals weeds were rare and there was balloon vine (Cardiospermum grandiflorum) in some shrubs and trees.

Table 6.36: Summary of impacts observed at 9_Ṅwaneḍi

Impacts	Intensity	Extent	Notes
Marginal zone			
Vegetation Removal	1	1	Minimal, mainly due to road crossings and cattle access points.
Alien Species Invasion	0	0	None
Terrestrial Species	0	0	None
Water Quantity	3	5	The Ṅwaneḍi dam is upstream of the site and caused flow reductions and reduced flood peaks.
Water Quality	1	5	Potentially affected by cattle drinking points and low-level crossings.
Erosion	2	3	Undercut banks and exposed roots common.
Floodbench			
Vegetation Removal	1.5	1	Mainly due to road crossings and cattle access points.
Alien Species Invasion	2	2	Ballon vine and Casteroil bush (*Ricinus communis*) with exotic annual weeds.
Terrestrial Species	0.5	1	Close to expectation
Water Quantity	1.5	5	The Ṅwaneḍi dam is upstream of the site and caused flow reductions and reduced flood peaks.
Water Quality	0	0	None
Erosion	0	0	None
MCB			
Vegetation Removal	2	2	Surrounding agricultural encroachment and cattle access points, also targeted wood removal.

Impacts	Intensity	Extent	Notes
Alien Species Invasion	1	2	Low, but present, mainly weeds but also Balloon vine and Casteroil bush.
Terrestrial Species	0.5	1	Close to expectation
Water Quantity	0	0	None
Water Quality	0	0	None
Erosion	2	1	Associated with road access areas along banks or to the river.

Table 6.37: List of plant species observed at 9_Ṅwaneḍi (Ex. = exotic, P = protected, y = yes, En. = endemic, SA = South Africa)

Species	Family	Common Name/s	Ex.	P	En.
Argemone Mexicana	PAPAVERACEAE	Yellow Mexican Poppy	*		
Bidens Pilosa	ASTERACEAE	Black Jack	*		
Breonadia salicina	RUBIACEAE	Matumi		y	
Buxus macowanii	BUXACEAE	Cape Box			SA
Cardiospermum grandiflorum	SAPINDACEAE	Ballon Vine	*		
Combretum microphyllum	COMBRETACEAE				
Commelina diffusa subsp. Diffusa	COMMELINACEAE				
Conyza bonariensis	ASTERACEAE	Horseweed	*		
Croton megalobotrys	EUPHORBIACEAE				
Ekebergia capensis	MELIACEAE	Cape ash; Essehout			
Faidherbia albida	FABACEAE	Anna Boom			
Ficus sycomorus	MORACEAE	Sycomore Fig			
Grewia flavescens	MALVACEAE	Sandpaper Raisin			
Grewia monticola	MALVACEAE				
Mimusops zeyheri	SAPOTACEAE	Transvaal red milkwood			
Nuxia oppositifolia	STILBACEAE				
Persicaria lapathifolia	POLYGONACEAE	Spotted Knotweed	*		
Phoenix reclinate	ARECACEAE	Wild date palm			
Phyllanthus reticulatus	PHYLLANTHACEAE	Potato bush			
Ranunculus multifidus	RANUNCULACEAE	Buttercup	*		
Ricinus communis	EUPHORBIACEAE	Cateroil Bush	*		
Schotia brachypetala	FABACEAE	Weeping boerbean			y
Senegalia schweinfurthii var. schweinfurthii	FABACEAE	River climbing thorn			
Setaria megaphylla	POACEAE	Broad-leaved bristle grass			
Tagetes minuta	ASTERACEAE	Khaki Weed	*		
Vachellia gerrardii	FABACEAE	Gerrard's Acacia			
Vachellia karroo	FABACEAE	Sweet Thorn			
Xanthocercis zambesiaca	FABACEAE	Nyala tree			
Ziziphus mucronate	RHAMNACEAE	Buffalo thorn			

Table 6.38: VEGRAI level 4 score and category for 9_Ṅwanedi

VEGRAI 4	9_Ṅwanedi					05 August 2022
Zone	Calculated Rating	Weighted Rating	Confidence	Rank	Weight	Notes:
Marginal zone	79.4	2.6	3.4	1.0	3.2	Weight = extent
Floodbench	78.6	25.3	3.2	2.0	32.3	Weight = extent
MCB	75.0	48.4	3.3	3.0	64.5	Weight = extent
VEGRAI (%)						76.3
VEGRAI Ecological Category						**C**
	Marginal zone	Floodbench	MCB			
VEGRAI %	79.4	78.6	75.0			
Ecological Category	B/C	B/C	C			

6.2.3.10 10_Latonyanda

The marginal zone and MCB on both banks of 10_Latonyanda were assessed on the 2nd of August 2022 in the Entabeni State Forest from just downstream of the log bridge for a distance of 110 m upstream. The present and reference states for each zone are described in **Table 6.39** and the ratings of impacts in **Table 6.40**. There were 17 indigenous and 10 exotic plants (**Table 6.41**). The PES score was 60.3%, an ecological category of **C/D** (**Table 6.42**).

Table 6.39: Description of reference and present state for 10_Latonyanda

Zone	Description of reference state	Description of present state
 Channel / marginal zone	The channel should be incised with a band of woody vegetation along the banks that would have shaded the channel and marginal zone.	The marginal zone is narrow and confined in an incised channel, with steep banks either unvegetated or with exposed roots with scattered clumps of non-woody vegetation (mostly *Colocasia esculenta, Cyclosorus interruptus, Commelina diffusa, Isolepis cernua*) and woody overhanging vegetation from the banks. Alien plant species included *Ageratum houstonianum, Colocasia esculenta* and *Ranunculus multifidus*, with overhanging *Caesalpinia decapetala* and *Sesbania punicea*.
 MCB	The MCB was expected to be woody riparian and terrestrial species with a clear riparian corridor mixed with savanna or forest species.	The MCB was narrow and steep and with tall trees, shrubs and forest grasses like *Setaria megaphylla*. The zone in shade and in turn shaded the channel creating overhanging habitats into the water. Common indigenous species included *Anthocleista grandiflora, Combretum erythrophyllum, Ficus sur, Nuxia floribunda, Trema orientalis* and *Trichilia emetica*. There were lots of exotics such as *Caesalpinia decapetala, Grevillea robusta, Psidium guajava* and *Solanum mauritianum.*

Table 6.40: Summary of impacts observed at 10_Latonyanda

Impacts	Intensity	Extent	Notes
Channel / Marginal zone			
Vegetation Removal	0	0	None
Alien Species Invasion	2.5	4	Annual alien weeds such as Ageratum houstonianum and perennials such as Sesbanea punicea, Caesalpinia decapetala.
Terrestrial Species	1	3	Present but not expected.
Water Quantity	0	0	None
Water Quality	2	5	Increased sediment inputs with runoff form forestry roads.
Erosion	0	0	None
MCB			
Vegetation Removal	1	4	Clearing for forestry and access, wood removal.
Alien Species Invasion	2.5	4	Invasion by exotics was high with Caesalpinia decapetala, Grevillea robusta, Psidium guajava and Solanum mauritianum.
Terrestrial Species	0	0	As expected, included forest species.
Water Quantity	0	0	None
Water Quality	0	0	None
Erosion	1	1	Localised footpaths eroded, roads input to zone.

Table 6.41: List of plant species observed at 10_Latonyanda (Ex. = exotic, P = protected, En. = endemic, SnA = southern Africa)

Species	Family	Common Name/s	Ex.	P	En.
Ageratum houstonianum	ASTERACEAE	Bluemink	*		
Anthocleista grandiflora	GENTIANACEAE	Forest fever tree			
Bidens pilosa	ASTERACEAE	Black Jack	*		
Bridelia micrantha	PHYLLANTHACEAE	Mitzeerie			
Caesalpinia decapetala	FABACEAE	Mauritius Thorn	*		
Colocasia esculenta	ARACEA	aMadumbe	*		
Combretum erythrophyllum	COMBRETACEAE	River bushwillow			SnA
Commelina diffusa subsp. diffusa	COMMELINACEAE				
Cyclosorus interruptus	THELYPTERIDACEAE	Water fern			
Dietes butcheriana	IRIDACEAE	Forest Iris			y
Diospyros mespiliformis	EBENACEAE	Jackal Berry			
Ficus sur	MORACEAE	Broomcluster Fig			
Grevillea robusta	PROTEACEAE	Australian silky oak	*		
Gymnanthemum myrianthum	ASTERACEAE	Blue bittertea			
Isolepis cernua var. cernua	CYPERACEAE				
Lantana camara	VERBENACEAE	Bird's Brandy	*		
Nuxia floribunda	STILBACEAE				
Psidium guajava	MYRTACEAE	Guava	*		
Pteridium aquilinum	DENNSTAEDTIACEAE	Bracken fern			
Ranunculus multifidus	RANUNCULACEAE	Buttercup	*		
Sesbania punicea	FABACEAE	Red Sesbania	*		
Setaria megaphylla	POACEAE	Broad-leaved bristle grass			
Sida dregei	MALVACEAE				
Solanum mauritianum	SOLANACEAE	Bugweed	*		
Trema orientalis	CANNABACEAE	Pigeonwood			
Trichilia emetica	MELIACEAE	Natal Mahogany			
Vachellia karroo	FABACEAE	Sweet Thorn			

Table 6.42: VEGRAI level 4 score and category for the 10_Latonyanda

VEGRAI 4	10_Latonyanda					02 August 2022
Zone	Calculated Rating	Weighted Rating	Confidence	Rank	Weight	Notes:
Marginal zone	61.3	12.3	3.1	1.0	20.0	Weight = extent
MCB	60.0	48.0	3.1	2.0	80.0	Weight = extent
VEGRAI (%)						60.3
VEGRAI Ecological Category						**C/D**
	Marginal zone	MCB				
VEGRAI %	61.3	60.0				
Ecological Category	C/D	C/D				

6.2.3.11 11_Mutshindudi

The marginal zone, floodbench and MCB on both banks of 11_Mutshindudi were assessed on the 2nd of August 2022 from pool below the falls for a distance of 200 m downstream. The present and reference states for zone are described in **Table 6.43** and the ratings of impacts in **Table 6.44**. There were 27 indigenous and 10 exotic plants (**Table 6.45)**. The PES score was 66.9%, an ecological category of C (**Table 6.46**).

Table 6.43: Description of reference and present state for 11_Mutshindudi

Zone	Description of reference state	Description of present state
 Marginal zone	The marginal zone should have woody rheophytic species on bedrock, such as *Breonadia salicina, Salix mucronata and Gomphostigma virgatum*) and reeds and other non-woody plants on alluvial bars and around pools.	The marginal zones had been disturbed by recent and past floods with clear flood damage to vegetation, and grazing and trampling pressure was also high. Habitats were rocky outcrops that supported *Breonadia salicina, Cyclosorus interruptus* and *Cyperus compressus,* consolidated alluvial bars that supported reeds (*Phragmites mauritianus*), lateral mixed bedrock / gravel bars that supported a linear arrangement of *B. salicina* and scattered *Salix mucronata*, and a high flow channel with grasses and sedges (*Cyperus alopecuroides, Cyperus eragrostis, Centella asiatica, Juncus lomatophyllus*). The exotic aquatic plant *Myriophyllum aquaticum* was present.
 Floodbench	The floodbench should be an extension of the marginal zone but with less sedges and taller trees of the same species.	The floodbench had been disturbed by recent and past floods with clear flood damage to vegetation, and grazing and trampling pressure was also high. Habitats included rocky outcrops that supported *Breonadia salicina,* localised areas of consolidated alluvial bars that supported reeds (*Phragmites mauritianus*), lateral mixed bedrock / gravel bars that supported a linear arrangement of *B. salicina* and *scattered Salix mucronata* and *Ficus sycomorus* (mostly saplings). Exotics were common, the main two were *Chromolaena odorata* and *Sesbania punicea.*
 MCB	The MCB is expected to be dominated by a dense woody riparian and terrestrial species with a clear riparian corridor.	The left MCB was steep, eroded and denuded of vegetation, there were a few terrestrial trees at the top of the bank, like *Sclerocarya birrea,* before the cultivated fields. The right bank was also steep and confined but well wooded. There were cleared access paths and overgrazing and trampling pressure was high. Exotic plants were common, the two main ones were *Chromolaena odorata* and *Lantana camara*.

Table 6.44: Summary of impacts observed at 11_Mutshindudi

Impacts	Intensity	Extent	Notes
Marginal/ Lower zone			
Vegetation Removal	3	5	Grazing, browsing and trampling pressure from livestock, access to river to cross and fish.
Alien Species Invasion	1	3	Exotic annual weeds such as *Ageratum houstonianum.*
Terrestrial Species	1	1	Higher than expected.
Water Quantity	3	5	Vondo dam upstream regulated flow.
Water Quality	0.5	5	Potentially affected by surrounding cultivation and settlements.
Erosion	1	1	Localised at access and watering points.
Floodbench			
Vegetation Removal	3	5	Grazing, browsing and trampling pressure from livestock, access to river to cross and fish.
Alien Species Invasion	2	3	Annual and perennial weeds
Terrestrial Species	1	2	Higher than expected
Water Quantity	2	5	Vondo dam upstream regulated flow.
Water Quality	0.5	5	Potentially affected by surrounding cultivation and settlements.
Erosion	2	2	Trampling along access paths.
MCB			
Vegetation Removal	3.5	4	Grazing, browsing and trampling pressure from livestock, access to river to cross and fish.
Alien Species Invasion	3	3	Exotic annual and perennial plants.
Terrestrial Species	1	1	Lower, wood removal and exotic species.
Water Quantity	0	5	None
Water Quality	0	5	None
Erosion	3	3	Trampling along access paths, eroded banks as evidenced by soil in the marginal zone.

Table 6.45: List of plant species observed at 11_Mutshindudi (Ex. = exotic, P = protected, y = yes, En. = endemic)

Species	Family	Common Name/s	Ex.	P	En.
Ageratum houstonianum	ASTERACEAE	Bluemink	*		
Andropogon contortis	POACEAE	Spear Grass			
Argemone mexicana	PAPAVERACEAE	Yellow Mexican Poppy	*		
Bidens pilosa	ASTERACEAE	Black Jack	*		
Breonadia salicina	RUBIACEAE	Matumi		y	
Centella asiatica	APIACEAE	Pennywort			
Chromolaena odorata	ASTERACEAE	Triffid weed	*		
Conyza bonariensis	ASTERACEAE	Horseweed	*		
Crinum moorei	AMARYLLIDACEAE				
Cyclosorus interruptus	THELYPTERIDACEAE	Water fern			
Cynodon dactylon	POACEAE	Coach grass			
Cyperus alopecuroides	CYPERACEAE				
Cyperus compressus	CYPERACEAE	Flat sedge			
Cyperus eragrostis	CYPERACEAE		*		
Dichrostachys cinerea	FABACEAE	Sickle Bush			
Diospyros lycioides subsp. lycioides	EBENACEAE	Bluebush			
Diospyros mespiliformis	EBENACEAE	Jackal Berry			
Euclea divinorum	EBENACEAE				
Ficus capreifolia	MORACEAE	River Sandpaper Fig			
Ficus sycomorus	MORACEAE	Sycomore Fig			
Gymnosporia senegalensis	CELASTRACEAE	Red spike-thorn			

Species	Family	Common Name/s	Ex.	P	En.
Juncus lomatophyllus	JUNCACEAE				
Lantana camara	VERBENACEAE	Bird's Brandy	*		
Myriophyllum aquaticum	HALORAGACEAE		*		
Pennisetum macrourum	POCEAE				
Philenoptera violacea	FABACEAE	Apple-leaf		y	
Phragmites mauritianus	POACEAE				
Pycreus betschuanus	CYPERACEAE				
Salix mucronata subsp. woodii	SALICACEAE				
Sclerocarya birrea subsp. caffra	ANACARDIACEAE	Marula		y	
Senegalia mellifera subsp. detinens	FABACEAE				
Sesbania punicea	FABACEAE	Red Sesbania	*		
Setaria incrassata	POACEAE	Vlei Bristle Grass			
Setaria sphacelata var. sericea	POACEAE	Golden Bristle Grass			
Sporobolus pyramidalis	POACEAE	Catstail Dropseed			
Tagetes minuta	ASTERACEAE	Khaki Weed	*		
Vachellia sieberiana var. woodii	FABACEAE	Flat-topped thorn			

Table 6.46: VEGRAI level 4 score and category for 11_Mutshindudi

VEGRAI 4	11_Mutshindudi					02 August 2022
Zone	Calculated Rating	Weighted Rating	Confidence	Rank	Weight	Notes:
Marginal zone	74.6	14.6	3.1	1.0	19.5	Weight = extent
Floodbench	70.6	22.4	3.1	2.0	31.7	Weight = extent
MCB	61.4	30.0	3.1	3.0	48.8	Weight = extent
VEGRAI (%)						66.9
VEGRAI Ecological Category						**C**
	Marginal zone	Floodbench	MCB			
VEGRAI %	74.6	70.6	61.4			
Ecological Category	C	C	C/D			

6.2.3.12 12_Luvuvhu

The marginal zone, floodbench and MCB on both banks of 12_Luvuvhu were assessed on the 3rd of August 2022 from where the road leaves the channel for a distance of 30 m upstream. The present and reference states for each zone are described in **Table 6.47** and the ratings of impacts in **Table 6.48.** There were 35 indigenous and 14 exotic plants (**Table 6.49**). The PES score was 66.5%, an ecological category of **C** (**Table 6.50**).

Table 6.47: Description of reference and present state for 12_Luvuvhu

Zone	Description of reference state	Description of present state
 Marginal zone	The marginal zone was expected to be dominated by reeds and with some trees on the bedrock sections, such as *Breonadia salicina* and *Gomphostigma virgatum.*	The marginal zone comprised reeds (*Phragmites mauritianus)*, and some trees (*B. salicina* and *Ficus caprefolia*) with water ferns (Cyclosorus interruptus) and forbs (*Persicaria lapathifolia*). *Gomphostigma virgatum* was absent.
 Floodbench	The floodbenches were expected to be dominated by reeds with some scattered woody shrubs.	The floodbench was dominated by reeds (P. mauritianus) with sedges (Cyperus alopecuroides, C. congestus, C. eragrostis) and shrubs (Ludwigia octovalvis, Pluchea dioscoridis, Phyllanthus reticulatus, Flueggea virosa). Sand bars supported woody trees (Ficus sycomorus, Combretum erythrophyllum, C. microphyllum) and the creeping grass, Cynodon dactylon. There were many exotic annual weeds and the perennial exotics Caesalpinia decapetala, Lantana camara, Sesbanea punicea and Senna didymobotrya.
 MCB	The MCB was expected to have a dense cover of woody riparian and terrestrial woodland trees and shrubs with a well vegetated understorey.	The MCB was dominated dense shrubs and trees, but there were also areas that were cleared for access, by wood removal and clearing for cultivation. Indigenous species included *Diospyros mespiliformis, Dichrostachys cinerea, Euclea divinorum, Gymnosporia senegalensis, Vachellia karroo* and *Ziziphus mucronata*. Exotic annual weeds were common perennial exotics were *Caesalpinia decapetala, Lantana camara* and *Senna didymobotrya.*

Table 6.48: Summary of impacts observed at 12_Luvuvhu

Impacts	Intensity	Extent	Notes
Marginal zone			
Vegetation Removal	1	1	Vegetation removal was localised and for accessto fish, wash clothes and cars and to cross.
Alien Species Invasion	0	0	None
Terrestrial Species	0	0	None
Water Quantity	2.5	5	The Vondo dam on the Mutshindudi River and the Nandoni dam on the Luvuvhu River were both some distance upstream but do regulate flow. There was a gauging weir just upstream.
Water Quality	2	5	The Mhinga WWTW was 2km upstream; rocks were covered with brown benthic algae; car and clothes washing at the bridge just upstream of the site.
Erosion	1	1	Associated with cleared areas (see removal above).
Floodbench			
Vegetation Removal	1	1	Vegetation removal was localised and for accessto fish, wash clothes and cars and to cross.

Impacts	Intensity	Extent	Notes
Alien Species Invasion	2	2	Exotic annual weeds species were common and perennial exotics were Caesalpinia decapetala, Lantana camara, Sesbanea punicea and Senna didymobotrya.
Terrestrial Species	1	2	Mainly *Vachellia karroo* saplings in the zone.
Water Quantity	2	5	The Vondo dam on the Mutshindudi River and the Nandoni dam on the Luvuvhu River were both some distance upstream but do regulate flow. There was a gauging weir just upstream.
Water Quality	1	5	The Mhinga WWTW was 2km upstream; rocks were covered with brown benthic algae; car and clothes washing at the bridge just upstream of the site.
Erosion	2	1	Associated with cleared areas (see removal above).
MCB			
Vegetation Removal	2	2	Woody vegetation removal was frequent and extensive in some areas for access paths and roads, wood removal and clearing for cultivation.
Alien Species Invasion	2	2	Exotic annual weeds were common and perennial exotics were *Caesalpinia decapetala, Lantana camara* and *Senna didymobotrya*.
Terrestrial Species	1	1	Slightly less than expected, also due to removal.
Water Quantity	0	0	None
Water Quality	0	0	None
Erosion	2	1	Associated with cleared areas (see removal above).

Table 6.49: List of plant species observed at 12_Luvuvhu (Ex. = exotic)

Species	Family	Common Name/s	Ex.
Ageratum houstonianum	ASTERACEAE	Bluemink	*
Argemone mexicana	PAPAVERACEAE	Yellow Mexican Poppy	*
Bidens pilosa	ASTERACEAE	Black Jack	*
Breonadia salicina	RUBIACEAE	Matumi	
Bridelia micrantha	PHYLLANTHACEAE	Mitzeerie	
Caesalpinia decapetala	FABACEAE	Mauritius Thorn	*
Centella asiatica	APIACEAE	Pennywort	
Combretum erythrophyllum	COMBRETACEAE	River bushwillow	
Combretum microphyllum	COMBRETACEAE		
Combretum molle	COMBRETACEAE		
Commelina diffusa subsp. diffusa	COMMELINACEAE		
Conyza bonariensis	ASTERACEAE	Horseweed	*
Cyclosorus interruptus	THELYPTERIDACEAE	Water fern	
Cynodon dactylon	POACEAE	Coach grass	
Cyperus alopecuroides	CYPERACEAE		
Cyperus congestus	CYPERACEAE		
Cyperus eragrostis	CYPERACEAE		*
Dichrostachys cinerea	FABACEAE	Sickle Bush	
Diospyros mespiliformis	EBENACEAE	Jackal Berry	
Eucalyptus camaldulensis	MYRTACEAE	River Red Gum	*
Euclea divinorum	EBENACEAE		
Ficus capreifolia	MORACEAE	River Sandpaper Fig	
Ficus sur	MORACEAE	Broomcluster Fig	
Ficus sycomorus	MORACEAE	Sycomore Fig	
Flueggea virosa	EUPHORBIACEAE	White-berry Bush	
Gymnosporia senegalensis	CELASTRACEAE	Red spike-thorn	
Juncus lomatophyllus	JUNCACEAE		
Lantana camara	VERBENACEAE	Bird's Brandy	*

Species	Family	Common Name/s	Ex.
Leonotis ocymifolia	LAMIACEAE		
Ludwigia octovalvis	ONAGRACEAE	Shrubby Ludwigia	
Panicum maximum	POACEAE	Guinea Grass	
Persicaria lapathifolia	POLYGONACEAE	Spotted Knotweed	*
Philenoptera violacea	FABACEAE	Apple-leaf	
Phragmites mauritianus	POACEAE		
Phyllanthus reticulatus	PHYLLANTHACEAE	Potato bush	
Pluchea bojeri	ASTERACEAE	Bushveld camphorweed	
Pycreus betschuanus	CYPERACEAE		
Schoenoplectus brachyceras	CYPERACEAE		
Senna didymobotrya	FABACEAE	Peanut butter cassia	*
Sesbania punicea	FABACEAE	Red Sesbania	*
Sida dregei	MALVACEAE		
Sporobolus ioclados	POACEAE	Pan Dropseed	
Syzygium guineense subsp. guineense	MYRTACEAE	Waterpear	
Tagetes minuta	ASTERACEAE	Khaki Weed	*
Terminalia sericea	COMBRETACEAE	Silver clusterleaf	
Vachellia karroo	FABACEAE	Sweet Thorn	
Vinca minor	APOCYNACEAE	Periwinkle	*
Xanthium strumarium	ASTERACEAE	Large Cocklebur	*
Ziziphus mucronata	RHAMNACEAE	Buffalo thorn	

Table 6.50: VEGRAI level 4 score and category for 12_Luvuvhu

VEGRAI 4	12_Luvuvhu					03 August 2022
Zone	Calculated Rating	Weighted Rating	Confidence	Rank	Weight	Notes:
Marginal zone	60.3	6.7	3.2	1.0	11.1	Weight = extent
Floodbench	68.0	34.0	3.3	2.0	50.0	Weight = extent
MCB	66.3	25.8	3.3	3.0	38.9	Weight = extent
VEGRAI (%)						66.5
VEGRAI Ecological Category						**C**
	Marginal zone	Floodbench	MCB			
VEGRAI %	60.3	68.0	66.3			
Ecological Category	C/D	C	C			

6.2.3.13 13_Mutale1

The aquatic and marginal zones, floodbench, MCB and seepage wetlands on both banks of 13_Mutale were assessed on the 3rd of August 2022 from the main riffle downstream of the seep wetland for a distance of 280 m. The present and reference states for each zone are described in **Table 6.51** and the ratings of impacts in **Table 6.52**. There were 36 indigenous and 3 alien species (**Table 6.53)**. The PES score was 80.1%, an ecological category of B/C (**Table 6.54**).

Table 6.51: Description of reference and present state for 13_Mutale1

Zone	Description of reference state	Description of present state
 Aquatic zone	The aquatic zone was in its reference state.	The aquatic zone vegetation was on the edges of the active channel where there were low velocities and comprised Potamogeton schweinfurthii, Stuckenia pectinatus and Nymphoides thunbergiana.
 Marginal zone	The marginal zone was expected to be narrow on the left bank and dispersed on the bedrock of the right bank, with non-woody grasses, sedges, reeds and some woody Syzygium cordatum, S. guineense or Breonadia salicina.	The marginal zone comprised a high cover of grasses (Ischaemum fasciculatum), sedges (Juncus lomatophyllus) and reeds (Phragmites mauritianus), and some overhanging trees. Grazing pressure was moderate. Breonadia salicina and Gomphostigma virgatum that prefer rocky habitats, were absent.
 Floodbench	The floodbench was expected to have non-woody grasses and sedges with some woody encroachment that should be held at bay by flooding with the correct frequency and magnitude. A woody woody Syzygium cordatum, S. guineense or Breonadia salicina.	The floodbench the riparian trees (Syzygium cordatum, Syzygium guineense, Combretum erythrophyllum) and grasses (Miscanthus junceus), and some grazed areas with sedges (Juncus lomatophyllus, Juncus oxycarpus, Schoenoplectus brachyceras) and grasses (Ischaemum fasciculatum). Grazing and trampling pressure was moderate and some wood had been removed. There were few exotic annual weeds and more perennial aliens like Senna didymobotrya and Sesbania punicea.
 MCB	The vegetation of the MCB was expected to be scant because of the proximity of the gorge downstream and the reduced alluvium available.	The MCB was absent on the left bank in the gorge. The right bank was narrow with tall trees and shrubs. There were cleared areas for access and wood removal. Common species included Grewia flavescens, Mimusops zeyheri, Nuxia oppositifolia, Tabernaemontana elegans and Dichrostachys cinerea.
 Seepage wetland	The seeps and pools of the wetland were expected to be perennially wet and support wetland and aquatic species.	There were seepage wetlands that merged with riparian habitats and were maintained by perennial seepage. This zone supported wetland species (mainly sedges and hydrophilic grasses such as Juncus lomatophyllus, Juncus oxycarpus, Cyperus dives, Schoenoplectus brachyceras, Ischaemum fasciculatum and includes the geophyte Crinum macowanii) and some aquatic plants (Potamogeton schweinfurthii, Nymphaea nouchali, Nymphoides thunbergiana) in perennial pools.

Table 6.52: Summary of impacts observed at 13_Mutale1

Impacts	Intensity	Extent	Notes
Aquatic			
Vegetation Removal	0	0	None
Alien Species Invasion	0	0	None
Terrestrial Species	0	0	None
Water Quantity	0.5	5	Only Lake Fundudzi upstream with a few localised small farm-style dams - water quantity should be close to natural.
Water Quality	0.5	5	Many and extensive wetlands upstream of the site along the Mutale River and tributaries likely to have cleaned water, so minimal impact.
Erosion	0	0	None
Marginal zone			
Vegetation Removal	1	1	Moderate grazing
Alien Species Invasion	1	1	Present but low, includes *Sesbanea punicea.*
Terrestrial Species	0	0	None
Water Quantity	0.5	5	Only Lake Fundudzi upstream with a few localised small farm-style dams - water quantity should be close to natural.
Water Quality	0.5	5	Many and extensive wetlands upstream of the site along the Mutale River and tributaries likely to have cleaned water, so minimal impact.
Erosion	0	0	None
Levee & Floodbench			
Vegetation Removal	2	1.5	Moderate grazing pressure, some access paths and roads, some wood removal.
Alien Species Invasion	1.5	2	Exotic annual weeds and also *S. punicea* and *Senna didymobotrya.*
Terrestrial Species	1	1	Close to expectation
Water Quantity	0	0	None
Water Quality	0	0	None
Erosion	0	0	None
MCB			
Vegetation Removal	2	1.5	Moderate grazing pressure, some access paths and roads, some wood removal.
Alien Species Invasion	1.5	2	Exotic annual weeds and also *Senna didymobotrya.*
Terrestrial Species	1	1	close to expectation to slightly higher
Water Quantity	0	0	None
Water Quality	0	0	None
Erosion	0	0	None

Table 6.53: Plant species observed at 13_Mutale1 (Ex. = exotic, P = protected, En. = endemic, SnA = southern Africa)

Species	Family	Common Name/s	Ex.	P	En.
Ageratum houstonianum	ASTERACEAE	Bluemink	*		
Agrostis lachnantha var. lachnantha	POACEAE	Bent grass			
Bidens pilosa	ASTERACEAE	Black Jack	*		
Centella asiatica	APIACEAE	Pennywort			
Combretum erythrophyllum	COMBRETACEAE	River bushwillow			SnA
Commelina diffusa subsp. diffusa	COMMELINACEAE				
Crinum macowanii	AMARYLLIDACEAE				
Cyclosorus interruptus	THELYPTERIDACEAE	Water fern			
Cynodon dactylon	POACEAE	Coach grass			
Cyperus congestus	CYPERACEAE				
Cyperus dives	CYPERACEAE	Giant sedge			
Dichrostachys cinerea	FABACEAE	Sickle Bush			

Species	Family	Common Name/s	Ex.	P	En.
Equisetum ramosissimum	EQUISETACEAE				
Floscopa glomerata	COMMELINACEAE				
Gomphocarpus fruticosus	APOCYNACEAE	Milkweed			
Grewia flavescens	MALVACEAE	Sandpaper Raisin			
Ischaemum fasciculatum	POACEAE	Hippo Grass			
Juncus lomatophyllus	JUNCACEAE				
Juncus oxycarpus	JUNCACEAE				
Ludwigia adscendens subsp. diffusa	ONAGRACEAE				
Mimusops zeyheri	SAPOTACEAE	Transvaal red milkwood			
Miscanthus junceus	POACEAE	Wireleaf daba grass			SnA
Morus alba var. alba	MORACEAE	White Mulberry	*		
Nuxia oppositifolia	STILBACEAE				
Nymphaea nouchali	NYMPHAEACEAE	Blue Water Lily			
Nymphoides thunbergiana	MENYANTHACEAE				
Phoenix reclinata	ARECACEAE	Wild date palm			
Phragmites mauritianus	POACEAE				
Potamogeton schweinfurthii	POTAMOGETONACEAE	Broad-leaved Pondweed			
Pycreus betschuanus	CYPERACEAE				
Ranunculus multifidus	RANUNCULACEAE	Buttercup	*		
Schoenoplectus brachyceras	CYPERACEAE				SA
Senna didymobotrya	FABACEAE	Peanut butter cassia	*		
Sesbania punicea	FABACEAE	Red Sesbania	*		
Stuckenia pectinatus	POTAMOGETONACEAE	Fennel-leaved Pondweed			
Syzygium cordatum subsp. cordatum	MYRTACEAE	Waterberry			
Syzygium guineense subsp. guineense	MYRTACEAE	Waterpear			
Tabernaemontana elegans	APOCYNACEAE	Toad tree			
Tagetes minuta	ASTERACEAE	Khaki Weed	*		

Table 6.54: VEGRAI level 4 score and category for 13_Mutale1

VERGAI 4	13_Mutale					03 August 2022
Zone	Calculated Rating	Weighted Rating	Confidence	Rank	Weight	Notes:
Aquatic zone	90.0	4.0	3.0	1.0	4.4	Weight = extent
Marginal zone	80.9	9.0	3.1	2.0	11.1	Weighted according to extent
Floodbench	79.8	53.2	2.2	3.0	66.7	Weighted according to extent
MCB	78.3	13.9	3.0	4.0	17.8	Weighted according to extent
VEGRAI (%)						80.1
VEGRAI Ecological Category						**B/C**
	Aquatic zone	Marginal zone	Floodbench	MCB		
VEGRAI %	90.0	80.9	79.8	78.3		
Ecological Category	A/B	B/C	B/C	B/C		

6.2.3.14 14_Mutale2

The marginal zone, lateral bars, flood benches and the MCB on both banks of 14_Mutale2 were assessed on the 4th of August 2022. The present and reference states for each zone are described in **Table 6.55** and the ratings of impacts in **Table 6.56.**

There were 30 indigenous and 8 exotic plants present (**Table 6.57**). The PES score was 83.5%, an ecological category of B (**Table 6.58**).

Table 6.55: Description of reference and present state for 14_Mutale2

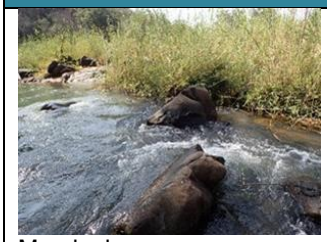
Zone	Description of reference state	Description of present state
 Marginal zone	The marginal zone should comprise non-woody vegetation (grasses, sedges, reeds) and some woody trees such as *Syzygium cordatum, S, guineense* or *Breonadia salicina.*	The marginal zone was dominated by reeds (*Phragmites mauritianus*) with open areas of bedrock and alluvial sand where there were some *Breonadia salicina* individuals.
 Lateral bar	Lateral bars are high disturbance flood habitats and are expected to be sparsely vegetated with non-woody plants adapted to regular flooding.	The upper zone comprised a mixture of sediments (bedrock, cobble, boulder, gravel and sand) with sparse vegetation cover of reeds, sedges and short shrubs. There were some exotic annual weeds such as *S. punicea* and *S. didymobotyrya* in low numbers.
 Flood bench	The floodbench should be dominated by non-woody grasses and sedges with some woody plants such as tall riparian tree species.	The floodbench comprised alluvial sands or with grasses and sedges and some tall riparian trees in low numbers, notably *Faidherbia albida*. The exotic annual weeds *S. punicea* and *S. didymobotrya* were in low numbers.
 MCB	The MCB should be a well-defined riparian woodland of tall dense to open trees and shrubs, and with some non-woody or open areas.	The MCB was a mixture of open and grassed areas with shrub and trees. There was sine bank erosion from past flooding. There were tall trees with a scant understorey. The indigenous riparian woody species included *Combretum imberbe, Dichrostachys cinerea, Diospyros mespiliformis, Euclea divinorum, Philenoptera violacea, Schotia brachypetala* and *Senegalia burkei.*

Table 6.56: Summary of impacts observed at 14_Mutale2

Impacts	Intensity	Extent	Notes
Marginal zone			
Vegetation Removal	0	0	None
Alien Species Invasion	0	0	None
Terrestrial Species	0	0	None
Water Quantity	0.5	5	Lake Fundudzi upstream with a few small farm-style dams - water quantity should be close to natural.
Water Quality	0	5	None
Erosion	0	0	None
Lateral bar			
Vegetation Removal	0	0	None
Alien Species Invasion	1	1	Present but low, includes Sesbanea punicea, Senna didymobotrya.
Terrestrial Species	0.5	1	Low, but as expected.
Water Quantity	0	0	None
Water Quality	0	0	None
Erosion	0	0	None
Floodbench			
Vegetation Removal	0	0	None
Alien Species Invasion	1	1	Present but low, includes Sesbanea punicea, Senna didymobotrya.
Terrestrial Species	0.5	1	Low, but as expected.
Water Quantity	0	0	None
Water Quality	0	0	None
Erosion	0	0	None
MCB			
Vegetation Removal	2	1.5	Moderate grazing pressure, some access paths and roads, some wood removal.
Alien Species Invasion	1.5	2	Annual weed species and *Senna didymobotrya.*
Terrestrial Species	1	1	Close to expectation to slightly higher.
Water Quantity	0	0	None
Water Quality	0	0	None
Erosion	0	0	None

Table 6.57: List of plant species observed at 14_Mutale2 (Ex. = exotic, P = protected, En. = endemic, SA = South Africa)

Species	Family	Common Name/s	Ex.	P	En.
Bidens pilosa	ASTERACEAE	Black Jack	*		
Breonadia salicina	RUBIACEAE	Matumi		y	
Combretum imberbe	COMBRETACEAE	Leadwood		y	
Commelina diffusa subsp. diffusa	COMMELINACEAE				
Conyza bonariensis	ASTERACEAE	Horseweed	*		
Cyclosorus interruptus	THELYPTERIDACEAE	Water fern			
Cynodon dactylon	POACEAE	Coach grass			
Cyperus alopecuroides	CYPERACEAE				
Cyperus congestus	CYPERACEAE				
Cyperus sexangularis	CYPERACEAE				
Dichrostachys cinerea	FABACEAE	Sickle Bush			
Diospyros mespiliformis	EBENACEAE	Jackal Berry			
Equisetum ramosissimum	EQUISETACEAE				
Eragrostis gummiflua	POACEAE	Gum grass			
Euclea divinorum	EBENACEAE				
Faidherbia albida	FABACEAE	Anna Boom			

Species	Family	Common Name/s	Ex.	P	En.
Ficus sycomorus	MORACEAE	Sycomore Fig			
Flueggea virosa	EUPHORBIACEAE	White-berry Bush			
Gardenia volkensii var volkensii	RUBIACEAE	Bushveld Gardenia			
Gomphocarpus fruticosus	APOCYNACEAE	Milkweed			
Grewia bicolor	MALVACEAE				
Gymnosporia senegalensis	CELASTRACEAE	Red spike-thorn			
Leonotis ocymifolia	LAMIACEAE				
Ludwigia adscendens subsp. diffusa	ONAGRACEAE				
Persicaria lapathifolia	POLYGONACEAE	Spotted Knotweed	*		
Philenoptera violacea	FABACEAE	Apple-leaf		y	
Phragmites mauritianus	POACEAE				
Phyllanthus reticulatus	PHYLLANTHACEAE	Potato bush			
Pluchea bojeri	ASTERACEAE	Bushveld Camphorweed			
Pycreus betschuanus	CYPERACEAE				
Ranunculus multifidus	RANUNCULACEAE	Buttercup	*		
Schotia brachypetala	FABACEAE	Weeping boerbean			y
Senegalia burkei	FABACEAE				SA
Senna didymobotrya	FABACEAE	Peanut butter cassia	*		
Sida dregei	MALVACEAE				
Tithonia diversifolia	ASTERACEAE		*		
Vachellia xanthophloea	FABACEAE	Fever Tree			
Vinca minor	APOCYNACEAE	Periwinkle	*		

Table 6.58: VEGRAI level 4 score and category for 14_Mutale2

VEGRAI 4	14_Mutale					04 August 2022
Zone	Calculated Rating	Weighted Rating	Confidence	Rank	Weight	Notes:
Marginal zone	89.6	7.9	3.0	1.0	8.8	Weight = extent
Lateral bar	84.5	49.7	3.1	2.0	58.8	Weight = extent
Floodbench	78.0	11.5	2.2	3.0	14.7	Weight = extent
MCB	81.3	14.3	3.0	4.0	17.6	Weight = extent
VEGRAI (%)						83.5
VEGRAI Ecological Category						**B**
	Marginal zone	Upper Zone - lateral bar	Floodbench	MCB		
VEGRAI %	89.6	84.5	78.0	81.3		
Ecological Category	A/B	B	B/C	B/C		

6.3 Riparian vegetation indicators

A list of generic indicators used for riparian vegetation is shown in **Table 6.59.** and a site- and species-specific list in **Table 6.60**. The linked indicators and reasons for their selection are given in **Table 6.61.**

Table 6.59: Riparian vegetation indicators and reasons for their selection

Indicator		Reasons for selection
Aquatic	Algae (biofilms and filamentous)	Algae provide food for instream fauna (fish and invertebrates) but can also affect habitat quality detrimentally.
	Aquatic vegetation	Aquatic vegetation provide habitat, including protection and breeding sites, and food for fish and invertebrates.
Wet Bank (inter-annual floods)	Marginal zone graminoids	This guild includes grasses, sedges and reeds and is important for bank stabilisation, habitat creation for aquatic fauna (both inundated instream and overhanging vegetation) and for food (seeds, fruits, rotting leaf material).
	Marginal zone broad-leaf plants	This guild includes broad-leaved hydrophytes that grow in the water as emergent vegetation or along the edges and provide important instream habitat for fish and aquatic invertebrates.
	Marginal zone woody plants	Marginal zone trees are important for bank stabilization, flood attenuation and provide overhanging shelter for instream fauna, particularly fish.
	Floodbench graminoids	This guild includes grasses, sedges and reeds growing in the lower zone. Non-woody vegetation is important for bank stabilization, grazing for animals and birds, habitat creation and for food (seeds, fruits, rotting leaf material) and habitats for fish spawning during flooding.
	Floodbench woody plants	Trees and shrubs are important for bank and sediment stabilization, flood attenuation and provide shelter and nesting sites for riparian fauna.
Dry Bank (inter-annual floods)	MCB riparian trees	MCB trees and shrubs are important for bank and sediment stabilization, flood attenuation and provide shelter and nesting sites for riparian fauna.
	MCB terrestrial woody plants	Terrestrial trees on the MCB should be transient and indicate terrestrialisation

Table 6.60: Site- and species-specific riparian vegetation indicators

Site	Generic Indicators	Specific Indicators
1_Lephalala	Algae	Biofilms and filamentous.
	Aquatic plants	Potamogeton schweinfurthii, Stuckenia pectinatus
	Marginal zone graminoids	Miscanthus junceus, Ischaemum fasciculatum
	Marginal zone broad-leaf plants	Ludwigia adscendens subsp. diffusa
	Floodbench graminoids	Miscanthus junceus
	Floodbench woody plants	Buxus macowanii Combretum erythrophyllum (saplings)
	MCB riparian trees	Combretum erythrophyllum
	MCB terrestrial woody plants	Carissa bispinosa, Dichrostachys cinerea, Terminalia sericea, Vachellia karroo, Ziziphus mucronata
2_Rietfontein	Algae	Biofilms and filamentous.
	Marginal zone graminoids	Cyperus sexangulari, Juncus rigidus, Agrostis lachnantha
	Marginal zone broad-leaf plants	Persicaria lapathifolia
	Floodbench graminoids	Cyperus sexangulari, Juncus rigidus, Agrostis lachnantha
	Floodbench woody plants	Gymnosporia glaucophylla, Phoenix reclinata
	MCB riparian trees	Schotia brachypetala, Combretum imberbe
3_Olifantspruit	Algae	Biofilms and filamentous.

Site	Generic Indicators	Specific Indicators
	Marginal zone graminoids	Phragmites australis, Juncus dregeanus, Juncus oxycarpus
	Marginal zone broad-leaf plants	Commelina diffusa
	MCB riparian trees	Combretum erythrophyllum
	MCB terrestrial trees	Combretum apiculatum, Dichrostachys cinerea, Diospyros lycioides subsp. Lycioides, Peltophorum africanum, Vachellia karroo, Ziziphus mucronata
4_Mogalakwena1	Algae	Biofilms and filamentous.
	Marginal zone graminoids	Phragmites mauritianus, Juncus lomatophyllus
	Floodbench graminoids	Agrostis lachnantha, Phragmites mauritianus
	Floodbench woody plants	Fluegea virosa
	MCB riparian trees	Combretum erythrophyllum
	MCB terrestrial woody plants	Vachellia karroo, Gymnosporia senegalensis and Ziziphus mucronata
5_Mogalakwena2	Algae	Biofilms and filamentous.
	Marginal zone graminoids	Juncus lomatophyllus, Cyperus digitatus, Ischaemum fasciculatum
	Marginal zone woody plants	Salix mucronata
	Floodbench graminoids	Juncus lomatophyllus, Cyperus digitatus, Ischaemum fasciculatum
	Floodbench woody plants	Salix mucronata
	MCB riparian trees	Faidherbia albida
	MBC terrestrial trees	Senegalia schweinfurthii
6_Kolope	Algae	Filamentous.
	Marginal zone graminoids	Setaria incrassata
	Floodbench graminoids	Setaria incrassata
	Floodbench woody plants	Flueggea virosa, Croton megalobotrys
	MCB riparian trees	Combretum imberbe, Croton megalobotrys, Philenoptera violacea, Salvadora australis
7_Sand	Floodbench graminoids	Sporobolus ioclados, Pennisetum macrourum
	MCB riparian trees	Combretum erythrophyllum
8_Nzhelele	Algae	Biofilms and filamentous.
	Marginal zone graminoids	Juncus oxycarpus, Cyperus sexangularis
	Marginal zone woody plants	Pluchea bojeri
	Floodbench woody plants	Pluchea bojeri
	MCB riparian trees	Diospyros mespiliformis, Schotia brachypetala, Xanthocercis zambesiaca
	MCB terrestrial woody plants	Dichrostachys cinerea, Euclea divinorum, Gymnosporia senegalensis, Vachellia karroo, Ziziphus mucronata.
9_Ṅwaneḍi	Algae	Biofilms and filamentous.
	Floodbench woody plants	Ficus sycomorus, Breonadia salicina, Combretum erythrophyllum, Faidherbia albida.
	MCB riparian trees	Schotia brachypetala, Xanthocercis zambesiaca, Faidherbia albida, Vachellia karroo
	MCB terrestrial woody plants	Eckebergia capensis, Mimusops zeyheri, Vachellia karroo, Ziziphus mucronata
10_Latonyanda	Algae	Biofilms and filamentous.
	Marginal zone graminoids	Cyclosorus interruptus
	Marginal zone broad-leaf plants	Commelina diffusa subsp. diffusa
	MCB riparian trees	Combretum erythrophyllum
	MCB terrestrial trees	Anthocleista grandiflora, Ficus sur, Nuxia floribunda, Trema orientalis and Trichilia emetica.
11_Mutshindudi	Algae	Biofilms and filamentous.

Site	Generic Indicators	Specific Indicators
	Marginal zone graminoids	Cyperus alopecuroides, Phragmites mauritianus
	Marginal zone woody plants	Breonadia salicina, Salix mucronata
	Floodbench woody plants	Breonadia salicina, Salix mucronata, Ficus sycomorus
	MCB riparian trees	Philenoptera violacea
	MCB terrestrial woody plants	Dichrostachys cinerea
12_Luvuvhu	Algae	Biofilms and filamentous.
	Marginal zone graminoids	Phragmites mauritianus
	Marginal zone woody plants	Breonadia salicina
	Floodbench graminoids	Phragmites mauritianus, Cyperus alopecuroides, C. congestus, C. eragrostis
	Floodbench woody plants	Ludwigia octovalvis, Pluchea dioscoridis, Phyllanthus reticulatus, Flueggea virosa, Ficus sycomorus, Combretum erythrophyllum
	MCB riparian trees	Ficus sycomorus
	MCB terrestrial woody plants	Dichrostachys cinerea, Euclea divinorum, Gymnosporia senegalensis, Vachellia karroo and Ziziphus mucronata
13_Mutale1	Algae	Biofilms and filamentous.
	Aquatic plants	Potamogeton schweinfurthii, Stuckenia pectinatus, Nymphoides thunbergiana
	Marginal zone graminoids	Ischaemum fasciculatum, Juncus lomatophyllus, Phragmites mauritianus
	Marginal zone broad-leaf plants	Cyclosorus interruptus and Ludwigia adscendens subsp. diffusa
	Marginal zone woody plants	Breonadia salicina and Gomphostigma virgatum
	Floodbench graminoids	Miscanthus junceus, Juncus lomatophyllus, Juncus oxycarpus, Schoenoplectus brachyceras and Ischaemum fasciculatum
	Floodbench woody plants	Syzygium cordatum, Syzygium guineense, Combretum erythrophyllum
	MCB riparian trees	Nuxia oppositifolia
	MCB terrestrial woody plants	Grewia flavescens, Mimusops zeyheri, Tabernaemontana elegans, Dichrostachys cinerea
14_Mutale2	Algae	Biofilms and filamentous.
	Marginal zone graminoids	Phragmites mauritianus
	Marginal zone broad-leaf plants	Commelina diffusa subsp. Diffusa, Cyclosorus interruptus, Ludwigia adscendens subsp. Diffusa, Persicaria lapathifolia
	Marginal zone woody plants	Breonadia salicina
	Floodplain graminoids	Phragmites mauritianus
	Floodbench woody plants	Faidherbia albida
	MCB riparian trees	Combretum imberbe, Diospyros mespiliformis, hilenoptera violacea, Schotia brachypetala

Table 6.61: Linked indicators and reasons for their selection

Indicator	Linked indicator	Reason
Algae	Dry duration	Algal growth is favoured in slower flowing shallow water and with no floods (Ewart-Smith 2012). A longer dry season = more algae.
	Dry min depth	Algal growth will increase in pools if depths are shallow enough to not limit light but if depths become too deep then light penetration becomes limiting. Deeper depths = more algae.
	Zero flow days	At zero flows algae will die off as habitat becomes limiting and temperatures increase. More zero flow days = less algae.
	Dry min 5d Q	Aquatic plants in sand prefer still or slow moving water and can be uprooted or break apart when experiencing fast moving water (www.cabi.org). Higher discharge disturbs plants breaking them apart. Higher dry season discharge = less algae.
	Wet max depth	If pools, or shallow areas become deep enough for light to become limiting algal growth will decline. Deeper pools = less algae.
	Bed erosion	Erosion of the channel bed scours bed sediments (Holomuzki and Biggs 2006) and filamentous algae (Biggs and Thomsen 1995). More ned erosion = less algae.
	Inundated sandy habitat	Algae grow on inundated sand. More inundated sand = more algae.
	Inundated cobble habitat	Algae grow on inundated cobbles. More inundated cobbles = more algae.
	Water clarity	Reduced light into the water column decreases growth and therefore biomass of filamentous algae (Hill 1996). Lower water clarity = less algae.
	Water temperature	Algal growth is favoured at higher temperatures up to a point. Mid-range temperatures = more algae.
	Nutrients	Algal growth is favoured with higher nutrient concentrations. More nutrients = more algae.
Aquatic plants	Dry duration	Aqautic plant species go dormant in the dry season. A longer dry season = less development and fewer aquatic plants.
	Dry min 5d Q	Aquatic plants grow in sand with still or slow moving water and can be uprooted or break apart by faster flow (www.cabi.org). Higher dry season discharge = less aquatic plants.
	Zero flow days	At zero flows aquatic vegetation will die off or go into dormancy as substrates and habitats are lost, and temperatures in pools increase retarding growth. More zero flow days = fewer aquatic plants.
	Wet shear stress	High levels of shear stress are likely to scour out aquatic vegetation. Higher shear stress in the wet season = fewer aquatic plants.
	Dry min depth	Aquatic plants must remain wet in to survive the dry season, especially in pools. Greater dry season depths = more aquatic plants.
	Wet Class 3 flood	Floods will scour out aquatic vegetation. More floods = less aquatic vegetation.
	Wet Class 4 flood	
	Backwaters and secondary channels	Aquatic plants in sand grow well in the slow flowing backwaters and secondary channels (www.cabi.org). More backwaters and secondary channels = more aquatic plants.
	Bed erosion	Erosion of the channel bed scours bed sediments (Holomuzki and Biggs 2006) and aquatic vegetation. Higher bed erosion = fewer aquatic plants.
	Inundated sandy habitat	Aquatic plants grow in wet sands (www.cabi.org). More wet sand = more aquatic plants.
	Pool depth	Some aquatic species prefer pools but pools that are too deep or too shallow limit growth. More pool depth = fewer aquatic plants.
	Water clarity	Reduced incident light hinders photosynthesis and growth of aquatic plants in sand (Bornette and Puijalon 2011). Less water clarity = fewer aquatic plants.
Marginal zone graminoids	Dry duration	Graminoids experience drought stress in the dry season. A shorter dry season = more graminoids.
	Dry min 5d Q	Flows in the dry season keep marginal soils moist that ensure survival during dormancy. Higher dry season discharge = more graminoids.
	Wet max 5d Q	Inundation is important during the growing season to ensure productivity and reproduction. Lower discharge = fewer graminoids.
	Zero flow days	Stream permanency is important for persistence of graminoids. More zero flow days = fewer graminoids.

Indicator	Linked indicator	Reason
	Wet class 2	This flood should inundate 50 - 100% of the graminoids, providing water and bringing nutrients for growth and reproduction. More class 2 floods = more graminoids.
	Wet class 3	This flood should inundate 100% of the graminoids and can scour some patches of the plant, creating areas where other species may take root. More class 3 floods = more graminoids.
	Wet class 4	This flood scours some of the marginal zone reducing the cover of some species and encouraging growth of others. They maintain heterogeneity and species diversity and boost reproductive success. More class 4 floods = more graminoids.
	Inset bench and bars	Inset benches and lateral bars provide habitat for graminoids. More inset benches and bars = more graminoids.
Marginal zone broad-leaf plants	Dry duration	Broad-leaf plants experience drought stress in the dry season. A shorter dry season = more broad-leaf plants.
	Dry min 5d Q	Flows in the dry season keep marginal soils moist that ensure survival during dormancy. Higher dry season discharge = more broad-leaf plants.
	Wet max 5d Q	Inundation is important during the growing season to ensure productivity and reproduction. Lower discharge = fewer broad-leaf plants.
	Zero flow days	Stream permanency is important for persistence of graminoids. More zero flow days = fewer broad-leaf plants.
	Wet ave shear stress	High levels of shear stress are likely to scour out broad-leaf plants. Higher shear stress in the wet season = fewer broad-leaf plants.
	Wet class 2	This flood should inundate 50 - 100% of the broad-leaf plants, providing water and bringing nutrients for growth and reproduction. More class 2 floods = more broad-leaf plants.
	Wet class 3	This flood should inundate 100% of the broad-leaf plants and can scour some patches of the plant, creating areas where other species may take root. More class 3 floods = more broad-leaf plants.
	Wet class 4	This flood scours some of the marginal zone reducing the cover of some species and encouraging growth of others. They maintain heterogeneity and species diversity and boost reproductive success. More class 4 floods = more broad-leaf plants.
	Inundated sandy habitat	Marginal zone broad-leaved vegetation requires moist or wet substrate in which to root. An increase in sand and gravel substrates will provide more rooting habitat, provide anchorage for resilience during flooding, as well as nutrients required for growth and production.
Marginal zone woody plants	Dry duration	Woody plants experience drought stress in the dry season. A shorter dry season = more woody plants.
	Dry min 5d Q	The dry season flows provide soil moisture to ensure survival and persistence during dormancy. Higher discharge in the dry season = more woody plants.
	Wet max 5d Q	Inundation is important during the growing season to ensure productivity and reproduction. Lower discharge in the wet season = fewer woody plants.
	Zero flow days	Stream permanency is important for persistence of woody plants. More zero flow days = fewer woody plants.
	Wet ave shear stress	Woody plants grow out into the channel in the wet season and are prone to scour. Higher shear stress = more scour and fewer woody plants.
	Wet class 2	This flood should inundate 50 - 100% of the woody plants providing water and nutrients for growth and reproduction. More class 2 floods = more woody plants.
	Wet class 3	This flood should inundate 100% of the woody plants and can scour some of the indicator. More class 3 floods = more woody plants.
	Wet class 4	This flood scours some of the woody plants reducing the cover of some species and encouraging growth of others. They maintain heterogeneity and species diversity and boost reproductive success. More class 4 floods = more woody plants.
	Inundated sandy habitat	Woody plants grow on inundated sandy habitat. More inundated sandy habitat = more woody plants.
Floodbench graminoids	Dry duration	Graminoids experience drought stress in the dry season. A shorter dry season = more graminoids.
	Dry min 5d Q	The dry season flows provide soil moisture to ensure survival and persistence during dormancy. Higher discharge in the dry season = more graminoids.
	Wet max 5d Q	Inundation is important during the growing season to ensure productivity and reproduction. Lower discharge in the wet season = fewer graminoids.

Indicator	Linked indicator	Reason
	Zero flow days	Stream permanency is important for persistence of woody plants. More zero flow days = fewer graminoids.
	Wet class 3	This flood should inundate some graminoids and scour others promoting regrowth. More class 3 floods = more graminoids.
	Wet class 4	This flood should inundate 100% of the graminoids and scour others promoting regrowth. More class 4 floods = more graminoids.
	1:2 class 5	These larger floods inundated and scour graminoids reducing the cover and promoting species richness. More 1:2 floods = fewer graminoids.
	Flood benches	Graminoids grow on flood benches. More flood benches = more graminoids.
	Flood bench woody plants	Graminoids are shaded out by woody plants. More woody plants = fewer graminoids.
Floodbench woody plants	Dry duration	Woody plants experience drought stress during the dry season. A longer dry season = more drought stress, lower growth and reproduction and fewer woody plants.
	Dry min 5d Q	Woody plants access groundwater which may become out of reach when discharges are low in the dry season. Lower dry season discharge = more drought stress, lower growth and reproduction and fewer woody plants.
	Wet max 5d Q	Discharges higher than median inundate the woody plants and provide water and nutrients that promote growth and reproduction. Low wet season discharges = fewer woody plants.
	Zero flow days	Woody plants have a competitive edge over terrestrial plants when water is freely available. More zero flow days put the woody plants under stress and may lead to their being replaced by drought tolerant terrestrial species = fewer woody plants.
	Wet class 3	This flood should inundate some woody plants providing water and nutrients promoting regrowth and reproduction. More class 3 floods = more woody plants.
	Wet class 4	This flood should inundate more of the woody plants providing water and nutrients promoting regrowth and reproduction. More class 4 floods = more woody plants.
	1:2 class 5	This flood inundates all the woody plants providing water and nutrients that promote growth and reproduction. More 1:2 floods = more woody plants.
	Flood benches	Woody plants grow on the flood benches. More flood benches = more woody plants.
MCB riparian trees	Zero flow days	MCB riparian trees have a competitive edge over terrestrial plants when water is freely available. More zero flow days put the woody plants under stress and may lead to their being replaced by drought tolerant terrestrial species = fewer woody plants.
	1:2 class 5	This flood inundates all the lower portion of the riparian trees providing water and nutrients that promote growth and reproduction and give them a competitive edge over terrestrial woody plants. More 1:2 floods = more MCB riparian trees.
	1:5 class 6	This flood inundates most of the riparian trees providing water and nutrients that promote growth and reproduction and give them a competitive edge over terrestrial woody plants. More 1:2 floods = more MCB riparian trees.
	1:10 Class 7	These larger floods scour riparian trees creating open areas where new plants may grow. More 1:10 floods = fewer riparian trees.
	1:20 Class 8	These extreme floods scour riparian trees and are a "resetting" event that promotes regrowth and species richness. More 1:20 floods = fewer riparian trees.
	Bank erosion	Riparian trees grow on the river banks and will fall into the channel as banks erode. More bank erosion = fewer riparian trees.
	MCB terrestrial trees	Riparian trees compete with terrestrial trees. Terrestrial trees have the advantage during droughts and riparian trees during wet years. More terrestrial trees = fewer riparian trees.
MCB terrestrial woody plants	1:5 class 6	The 1:5 inundates much of the river bank and drowns out recruiting, or scours adult, terrestrial woody plants. More 1:5 floods = fewer terrestrial woody plants.
	1:10 Class 7	Same as the 1:5 but more severe. More 1:10 = fewer terrestrial woody plants.
	1:20 Class 8	These extreme floods scour terrestrial and are a "resetting" event that promotes regrowth and species richness of riparian trees. More 1:20 floods = fewer terrestrial woody plants.
	Bank erosion	Terrestrial trees grow on outer edge of the riparian zone and will fall into the channel as banks erode. More bank erosion = fewer terrestrial woody plants.

6.4 Status and trends

6.4.1 Algal biofilms

Relevant at 1_Lephalala, 2_Rietfontein, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2.

The main anthropogenic drivers of indicator status were:

- Alterations to flow regimes with an emphasis on lower flows.
- Increased nutrient inputs from changes in land-use.
- Increased turbidity in the water column.
- Altered bed scour and/or embeddedness.

Assuming the 2022 quantity of algal biofilms was 100%, the estimated quantity in:

c. 1900 was:

- 110% at 1_Lephalala, 2_Rietfontein, 3_Olifantspruit, 112% at 4_Mogalakwena1, 90% at 9_Ṅwaneḍi, 105% at 12_Luvuvhu and 95% at 11_Mushindudi because naturalised flows inundated more cobble habitats and water clarity was better but counter balanced by lower levels of nutrients.
- 110% at 5_Mogalakwena2 because naturalised flows inundated more cobble habitats and water clarity was better but counter balanced by lower levels of nutrients and increased bed erosion.
- 90% at 8_Nzhelele due to fewer nutrients.
- 100% at 10_Latonyanda because there were similar flow and habitat conditions as PES (2022).
- 105% at 13_Mutale1 and 14_Mutale2 because flows in the Mutale River were near natural despite some abstraction, so slightly more flow in the 1900s would have made more habitat available.

c. 1960 was:

- 110% at 1_Lephalala, 2_Rietfontein and 3_Olifantspruit, 90% at 9_Ṅwaneḍi, 95% at 11_Mutshindudi because flows were closer to natural and inundated more cobble habitats and water clarity was better.
- 100% at 4_Mogalakwena1, 5_Mogalakwena2 and 12_Luvuvhu because the upstream dams would have regulated and reduced flow same as PES (2022) (Donkerpoort Dam in 1945, Doorndraai Dam in 1952 and Albasini Dam in 1952).
- 90% at 8_Nzhelele due to fewer nutrients.
- 100% at 10_Latonyanda because there were similar flow and habitat conditions as PES (2022).
- 105% at 13_Mutale1 and 14_Mutale2 because flows in the Mutale River were near natural despite some abstraction, so slightly more flow in the 1960s would increase made more habitat available.

c. 2000 was:

- 100% at 1_Lephalala, 2_Rietfontein, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalaknwena2, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Muthshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2 because flows inundated about the same amount of cobble habitats as PES (2022) and water quality was approximately the same.

6.4.2 Filamentous algae

Relevant at 1_Lephalala, 2_Rietfontein, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2.

The main anthropogenic drivers of indicator status were:

- Alterations to flow regimes with an emphasis on lower flows.
- Increased nutrient inputs from changes in land-use.
- Increased turbidity in the water column.
- Altered bed scour and/or embeddedness.
-

Assuming the 2022 quantity of filamentous algae was 100%, the estimated quantity in:

c. 1900 was:

- 110% at 1_Lephalala, 3_Olifantspruit and 95% at 9_Ṅwaneḍi, 11_Mutshindudi and 110% at 12_Luvuvhu because naturalised flows inundated more cobble habitats and water clarity was better but countered by lower levels of nutrients.
- 90% at 2_Rietfontein, 8_Nzhelele because nutrients were less than PES (2022).
- 110% at 4_Mogalakwena1 and 5_Mogalakwena2 because naturalised flows inundated more cobble and sandy habitats, and water clarity was better but counter balanced by lower levels of nutrients and increased bed erosion.
- 102% at 6_Kolope since the site was near natural.
- 100% at 10_Latonyanda because there were similar flow and habitat conditions as PES (2022).
- 105% at 13_Mutale1 and 14_Mutale2 because flows in the Mutale River were near natural despite some abstraction, so slightly more flow in the 1900s would have made more habitat available.

c. 1960 was:

- 110% at 1_Lephalala, 3_Olifantspruit, 90% at 9_Ṅwaneḍi and 95% at 11_Mutshindudi because naturalised flows inundated more cobble habitats and water clarity was better but counter balanced by lower levels of nutrients.
- 90% at 2_Rietfontein because nutrients were less than PES (2022).
- 100% at 4_Mogalakwena1 and 5_Mogalakwena2 because upstream dams regulated and reduce flows similar to PES (2022) (Donkerpoort Dam in 1945 and Doorndraai in 1952).
- 102% at 6_Kolope since the conditions were near natural.
- 90% at 8_Nzhelele due to lower levels of nutrients.
- 100% at 10_Latonyanda and 12_Luvuvhu (since Albasini Dam was commissioned in 1952) because there were similar flow and habitat conditions as PES (2022).
- 105% at 13_Mutale1 and 14_Mutale2 because flows were near natural but with some abstraction, so slightly more flow in the 1960s would have made more habitat available.

c. 2000 was:

- 100% at 1_Lephalala, 2_Rietfontein, 3_Olifantspruit, 8_Nzhelele, 10_Latonyanda, 11_Mutshindudi, 13_Mutale1 and 14_Mutale 2 because flows inundated about the same amount of sandy and cobble habitats as PES (2022).
- 100% at 4_Mogalakwena1, 5_Mogalakwena2, 9_Ṅwaneḍi and 12_Luvuvhu because upstream dams would have regulated and reduced flow same as PES (2022).
- 102% at Kolope since the site was near natural.

6.4.3 Aquatic plants

Relevant at 1_Lephalala and 13_Mutale1.

The main anthropogenic drivers of indicator status were:

- Alterations to flow regimes with an emphasis on lower flows.
- Increased nutrients and turbidity because of changes in land-use.

Assuming the 2022 quantity of aquatic vegetation was 100%, the estimated quantity in:

c. 1900 was:

- 110% at 1_Lephalala due to a shorter dry season and improved water clarity.
- 100% at 13_Mutale1 because there was a similar flow regime and nutrient load to PES (2022).

c. 1960 was:

- 110% at 1_Lephalala due to a shorter dry season and improved water clarity.
- 100% at 13_Mutale1 because there was a similar flow regime and nutrient load to PES (2022).

c. 2000 was:

- 100% at 1_Lephalala because flow regime and water quality was like PES (2022)
- 100% at 13_Mutale1 because there was a similar flow regime and nutrient load to PES (2022).

6.4.4 Marginal zone graminoids

Relevant at 1_Lephalala, 2_Rietfontein, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 8_Nzhelele, 9_Ṅwanedi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2.

The main anthropogenic drivers of indicator status were:

- Exotic plant species competing for similar habitats and resources.
- Flow regulation and reduction.
- Vegetation removal from cattle trampling and grazing pressure, warthog tillage/foraging and clearing along localised access paths.
- Additional inset bench habitat due to flow reduction.
- Incision and scour due to proximity of low-level crossings.

Assuming the 2022 quantity of marginal zone graminoids was 100%, the estimated quantity in:

c. 1900 was:

- 110% at 1_Lephalala, 10_Latonyanda and 11_Mutshindudi because there were no exotic plants and higher unregulated flows that meant higher cover and density of graminoids, but higher flows also reduced their habitat of inset bench and sand bars.
- 100% at 2_Rietfontein and 105% at 6_Kolope because the sites were near natural.
- 110% at Olifantspruit because there was less scour and therefore more alluvial habitat.
- 120% at 4_Mogalakwena1 and 12_Luvuvhu, 112% 5_Mogalakwena2 and 110% at 8_Nzhelele because naturalised flows provided better opportunities for recruitment and expansion, a longer growing period and less desiccation stress but were countered by increased bank scour and less inset bench habitat.
- 100% at 13_Mutale1 and 14_Mutale2 because the flow regime was similar to PES (2022).

c. 1960 was:

- 105% at 1_Lephalala, 6_Kolope and 12_Luvuvhu because there was less grazing and animal trampling, otherwise the sites were close to PES (2022).
- 100% at 2_Rietfontein because the site was near natural.
- 100% at 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 10_Latonyanda, 11_Mutshindudi, 13_Mutale1 and 14_Mutale2 with similar conditions and impacts to PES (2022).
- 110% at 8_Nzhelele because naturalised flows provided better opportunities for recruitment and expansion, a longer growing period and less desiccation stress but were countered by increased bank scour and less inset bench habitat.

c. 2000 was:

- 100% at 1_Lephalala, 2_Rietfontein, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 8_Nzhelele, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2 because conditions were the same as PES (2022).

6.4.5 Marginal zone woody plants

Relevant at 5_Mogalakwena2, 8_Nzhelele, 10_Mutshindudi, 12-Luvuvhu, 13_Mutale1, 14_Mutale2.

The main anthropogenic drivers of indicator status were:

- Flow regulation and reduction.
- Vegetation removal from cattle trampling and grazing pressure, warthog tillage/foraging and clearing along localised access paths.
- Incision and scour due to proximity of low-level crossings.
- Competition with high density reed encroachment.

Assuming the 2022 quantity of marginal zone woody plants was 100%, the estimated quantity in:

c. 1900 was:

- 190% at 5_Mogalakwena2 because naturalised flows provided better opportunities for recruitment and expansion, a longer growing period and less desiccation stress but were countered by increased bank scour and less inset bench habitat.
- 100% at 8_Nzhelele because there was 1 species that is rheophytic and shifts its position as flows change.
- 110% at 11_ Mutshindudi because naturalised flows provide better opportunities for recruitment and expansion, a longer growing period and less desiccation stress.
- 170% at 12_Luvuvhu because naturalised flows provided better opportunities for recruitment and expansion, a longer growing period and less desiccation stress, and competition from reeds would have been less.
- 105% at 13_Mutale1 (Ri33) because the flow regime was similar to PES (2022) with less grazing and trampling pressure.
- 110% at 14_Mutale2 (Ri34) because the flow regime was similar to PES (2022) with less scour at the weir and less browsing pressure.

c. 1960 was:

- 100% at 5_Mogalakwena2 because conditions were similar to PES (2022) since Donkerpoort and Doorndraai Dams were commissioned in 1945 and 1952 respectively.
- 100% at 8_Nzhelele because there was 1 species that is rheophytic and shifts its position as flows change.

- 110% at Mutshindudi because naturalised flows provide better opportunities for recruitment and expansion, a longer growing period and less desiccation stress.
- 110% at Luvuvhu because Albasini Dam (commissioned in 1952) regulated flow and reed densities would have started to increase.
- 105% at Mutale (Ri33) because the flow regime was similar to PES (2022) with less grazing and trampling pressure.
- 110% at Mutale (Ri34) because the flow regime was similar to PES (2022) with less scour at the weir and less browsing pressure.

c. 2000 was:

- 100% at 5_Mogalakwena2, 8_Nzhelele, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2 because conditions were similar to PES (2022).

6.4.6 Marginal zone broad-leaf plants

Relevant at 1_Lephalala, 2_Rietfontein, 3_Olifantspruit, 10_Latonyanda, 13_Mutale1 and 14_Mutale2.

The main anthropogenic drivers of indicator status were:

- Exotic plant species competing for similar habitats and resources.
- Flow regulation and reduction.
- Vegetation removal due to cattle trampling and grazing pressure, warthog tillage / foraging and clearing along localised access paths.
- Additional inset bench and sand bar habitat due to flow reduction.
- Incision and scour due to proximity of low-level crossings.

Assuming the 2022 quantity of marginal zone broad-leaf vegetation was 100%, the estimated quantity in:

c. 1900 was:

- 80% at 1_Lephalala because higher flows reduced the area of inset benches and sand bars where broad-leaf plants grow.
- 100% at 2_Rietfontein as the site was near natural.
- 110% at 3_Olifantspruit, 10_Latonyanda because there was less scour and more alluvial habitat where the plants grow.
- 100% at 13_Mutale1 and 14_Mutale2 because the flow regime was the same as PES (2022).

c. 1960 was:

- 80% at 1_Lephalala because higher flows reduced the area of inset benches and sand bars where broad-leaf plants grow.
- 100% at 2_Rietfontein as the site is near natural.
- 100% at 3_Olifantspruit, 10_Latonyanda, 13_Mutale1 and 14_Mutale2 with similar conditions and impacts to present day.

c. 2000 was:

- 90% at 1_Lephalala because flow reduction resulted in an increase in area of habitat (inset benches and sand bars) although elevated grazing and trampling restricted spread.
- 100% at 2_Rietfontein as the site is near natural.
- 100% at 3_Olifantspruit with similar conditions and impacts to present day.

- 100% at 3_Olifantspruit, 10_Latonyanda, 13_Mutale1 and 14_Mutale2 with similar conditions and impacts to present day.

6.4.7 Flood bench Graminoids

Relevant at 1_Lephalala, 2_Rietfontein, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 7_Sand, 12_Luvuvhu, 13_Mutale, 14_Mutale.

The main anthropogenic drivers of indicator status were:

- Exotic plant species competing for similar habitats and resources.
- Flow regulation and reduction in flood peaks and flooding frequency.
- Vegetation removal due to cattle trampling and grazing pressure, foraging and clearing along localised access paths and crossings.
- High grazing and trampling pressure from wild animals such as elephants and buffalo.
- Terrestrialisation of the flood bench because of reduced flooding frequency magnitude and duration.
- Localised erosion along denuded access paths.
- Competition from high density reed encroachment.
-

Assuming the 2022 quantity of flood bench graminoids is 100%, the estimated quantity in:

c. 1900 was:

- 120% at 1_Lephalala and 110% 12_Luvuvhu because higher naturalised flows and floods boosted growth and recruiting opportunities, grazing pressure was lower, and competition from reeds was less at 12_Luvuvhu.
- 100% at 2_Rietfontein and 7_Sand as the site was near natural.
- 130% at 4_Mogalakwena1 because naturalised flows and floods provided better opportunities for recruitment and expansion, a longer growing period and less desiccation stress but were countered by reduced flood bench habitat and increased competition from bench woody vegetation. Disturbance was less (people, livestock and exotic plants).
- 102% at 5_Mogalakwena2 as flows were similar to PES (2022).
- 110% at 6_Kolope because grazing and trampling pressure were lower.
- 105% at 13_Mutale1 because the flow regime was close to PES (2022) and grazing pressure and trampling pressure were lower.
- 100% at 14_Mutale2 because the flow regime, grazing pressure and trampling were the same as PES (2022).

c. 1960 was:

- 120% at 1_Lephalala because higher naturalised flows and floods boosted growth and recruiting opportunities and grazing pressure was lower.
- 110% at 4_Mogalakwena1 because flows were similar to PES (2022) since Donkerpoort dam was commissioned in 1945 and Doorndraai in 1952. Vegetation disturbance and removal was less than PES (2022).
- 100% at 5_Mogalakwena2 and 12_Luvuvhu because flows and pressures were the same as PES (2022).
- 110% at 6_Kolope because grazing and trampling pressure were lower.
- 100% at the 7_Sand River because conditions were near natural.

- 105% at 13_Mutale1 because the flow regime was close to PES (2022) and grazing pressure and trampling pressure were lower.
- 100% at 14_Mutale2 because the flow regime, grazing pressure and trampling were the same as PES (2022).

c. 2000 was:

- 110% at 1_Lephalala due to elevated (relative to earlier periods) grazing and trampling pressure by livestock and clearing for access.
- 100% at 2_Rietfontein as the site was near natural.
- 100% at 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2 as the flow regime and pressures were similar to PES (2022).
- 100% at 7_Sand River as conditions are near natural.

6.4.8 Flood bench woody plants

Relevant at 1_Lephalala, 2_Rietfontein, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 8_Nzhelele, 9_Ṅwaneḍi, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2.

The main anthropogenic drivers of indicator status were:

- Exotic plant species competing for similar habitats and resources.
- Flow regulation and reduction in flood peaks and flooding frequency.
- Vegetation removal due to cattle trampling and grazing pressure, foraging, and clearing along localised access paths.
- Terrestrialisation because of reduced flooding frequency, magnitude and duration.
- Wood removal for firewood.
- Bank erosion.
- High browsing and trampling pressure from megaherbivores.

Assuming the 2022 quantity of flood bench woody vegetation was 100%, the estimated quantity in:

c. 1900 was:

- 120% at 1_Lephalala, 110% at 2_Rietfontein and 125% at 8_Nzhelele because higher naturalised flows and floods boosted growth and recruitment, and grazing pressure by livestock was less.
- 120% at 4_Mogalakwena1, 200% at 5_Mogalakwena2, 140% at 9_Ṅwaneḍi because naturalised flows and floods provided better opportunities for recruitment and expansion, there was a longer growing period and less desiccation stress but this was countered by reduced flood bench habitat. Disturbance by people and livestock was lower, with fewer aliens and less vegetation removal.
- 110% at 6_Kolope because grazing and trampling pressure were lower.
- 110% at 10_Mutshindudi and 150% at 12_Luvuvhu because naturalised flows and floods provided better opportunities for recruitment and expansion, there was a longer growing period and less desiccation stress.
- 105% at 13_Mutale1 and 14_Mutale2 because the flow regime was close to PES (2022) and grazing and tramling pressure were lower.

c. 1960 was:

- 120% at 1_Lephalala, 6_Kolope because flows were the same as PES (2022) and there was less grazing and trampling by animals.
- 110% at Rietfontein because higher flows and floods boosted growth and reproduction.

- 110% at 4_Mogalakwena1 and 5_Mogalakwena2 because flows were same as PES (2022) and there was less vegetation disturbance and removal.
- 120% at 8_Nzhelele, 9_Ṅwaneḍi because higher flows and floods boosted growth, reproduction and recruiting opportunities, grazing pressure by livestock was, there were fewer exotic plants and vegetation removal was less.
- 110% at 11_Mutshindudi because higher flows and floods boosted growth, reproduction and recruiting opportunities, there was a longer growing period and less desiccation stress.
- 110% at 12_Luvuvhu because conditions were similar to PES (2022) but the Albasini Dam (commissioned in 1952) started to effect change, such as increased densities of reeds.
- 105% at 13_Mutale1 and 14_Mutale2 because flows were the same as PES (2022) and grazing and trampling were lower.

c. 2000 was:

- 110% at 1_Lephalala due to elevated (relative to earlier periods) grazing and trampling pressure by livestock and clearing for access, as well as competition for habitats and resources by exotic plants.
- 110% at 2_Rietfontein and 8_Nzhelele because higher flows and floods boosted growth, reproduction and recruitment.
- 100% at 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 9_Ṅwaneḍi, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2 because flows and pressures were the same as PES (2022).

6.4.9 MCB riparian trees

Relevant at all sites.

The main anthropogenic drivers of indicator status were:

- Exotic plant species competing for similar habitats and resources.
- Vegetation removal from cattle trampling and grazing pressure, foraging, and clearing along localised access paths and for agriculture.
- Terrestrialisation of banks.
- Wood removal for firewood.
- Bank erosion resulting in loss of vegetation.
- High browsing and breakage from megaherbivores.

Assuming the 2022 quantity of MCB riparian trees was 100%, the estimated quantity in:

c. 1900 was:

- 110% at 1_Lephalala, 125% at 4_Mogalakwena1, 180% at 5_Mogalakwena2 and 105% at 12_Luvuvhu because higher flows and floods boosted growth, reproduction and recruitment, and grazing pressure and wood removal were less.
- 100% at 2_Rietfontein as the site was near natural.
- 120% at 3_Olifantspruit because there was less vegetation removal, less bank erosion and less competition for resources and habitats from exotic plants.
- 110% at 6_Kolope because there was less browsing, trampling and destructive pressure from megaherbivores.
- 85% at 7_Sand because there were more megaherbivores and floods that uprooted trees.

- 100% at 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi because conditions were same as PES (2022).
- 105% at 13_Mutale1 and 14_Mutale2 because the flow regime was close to PES (2022) and grazing and trampling pressure were lower.

c. 1960 was:

- 110% at 1_Lephalala, 110% at 4_Mogalakwena1 and 140% at 5_Mogalakwena2 because higher flows and floods boosted growth, reproduction and recruitment, and grazing pressure and wood removal were less.
- 100% at 2_Rietfontein as the site was near natural.
- 110% at 3_Olifantspruit because there was less vegetation removal, less bank erosion and less competition for resources and habitats from exotic plants.
- 110% at 6_Kolope because there was less browsing, trampling and destructive pressure from megaherbivores.
- 85% at 7_Sand River because woody encroachment started since the Turfloop Dam was commissioned in 1955.
- 100% at 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi and 12_Luvuvhu because conditions were same as PES (2022).
- 105% at 13_Mutale1 and 14_Mutale2 because the flow regime was close to PES (2022) and grazing and trampling pressure were lower.

c. 2000 was:

- 100% at all sites because conditions were same as PES (2022).

6.4.10 MCB terrestrial woody plants

Relevant at 1_Lephalala, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi and 12_Luvuvhu.

The main anthropogenic drivers of indicator status were:

- Exotic plant species competing for similar habitats and resources.
- Vegetation removal from cattle trampling and grazing pressure, foraging, and clearing along localised access paths and for agriculture.
- Wood removal for firewood.
- Bank erosion.

Assuming the 2022 quantity of MCB terrestrial trees was 100%, the estimated quantity in:

c. 1900 was:

- 90% at 1_Lephalala and 11_Mutshindudi, and 85% at 4_Mogalakwena1 because higher flows and floods prevented terrestrialisation.
- 110% at 3_Olifantspruit, 115% at 5_Mogalakwena2, 125% at 8_Nzhelele, 9_Ṅwaneḍi and 120% at 12_Luvuvhu because there was less vegetation removal, less bank erosion and less competition exotic plants.
- 90% at Latonyanda – there would have been less trees before the onset of forestry.

c. 1960 was:

- 90% at 1_Lephalala and 4_Mogalakwena1, and 95% at 11_Mutshindudi because higher flows and floods prevented terrestrialisation.

- 105% at 3_Olifantspruit; 110% at 5_Mogalakwena2, 8_Nzhelele and 9_Ṅwaneḍi, and; 115% at 12_Luvuvhu because there was less vegetation removal, less bank erosion and less competition exotic plants.
- 100% at 10_Latonyanda with the advent of forestry with higher levels of disturbance and practices that favoured trees.

c. 2000 was:

- 100% at 1_Lephalala, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi and 12_Luvuvhu because flows and pressures were same as PES (2022).

6.4.11 Summary of Trends

A summary of all the trends is provided in **Table 6.62**.

Table 6.62: Summary of trends per site per indicator for riparian vegetation

Indicator	Year	1_Lephalala	2_Rietfontein	3_Olifantspruit	4_Mogalakwena1	5_Mogalakwena2	6_Kolope	7_Sand	8_Nzhelele	9_Ṅwaneḍi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale1	14_Mutale2
Algal biofilms	1900	110	110	110	112	110			90	90	100	95	105	105	105
	1960	110	110	110	100	100			90	90	100	95	100	105	105
	2000	100	100	100	100	100			100	100	100	100	100	100	100
Filamentous algae	1900	110	90	110	110	110	102		90	90	100	95	110	105	105
	1960	110	90	110	100	100	102		90	90	100	95	100	105	105
	2000	100	100	100	100	100	102		100	100	100	100	100	100	100
Aquatic plants	1900	110												100	
	1960	110												100	
	2000	100												100	
Marginal zone graminoids	1900	110	100	110	120	112	105		110		110	110	120	100	100
	1960	105	100	100	100	100	105		110		100	100	105	100	100
	2000	100	100	100	100	100	100		100		100	100	100	100	100
Marginal zone broadleaf plants	1900	80	100	110							110			100	100
	1960	80	100	100							100			100	100
	2000	90	100	100							100			100	100
Marginal zone woody plants	1900					190			100			110	170	105	110
	1960					100			100			110	110	105	110
	2000					100			100			100	100	100	100
Flood bench graminoids	1900	120	100		130	102	110	100					110	105	100
	1960	120	100		110	100	110	100					100	105	100
	2000	110	100		110	100	100	100					100	100	100
Flood bench woody plants	1900	120	110		120	200	110		125	140		110	150	105	115
	1960	120	110		110	140	110		120	120		110	110	105	110
	2000	110	110		100	100	100		110	100		100	100	100	100

Indicator	Year	1_Lephalala	2_Rietfontein	3_Olifantspruit	4_Mogalakwena1	5_Mogalakwena2	6_Kolope	7_Sand	8_Nzhelele	9_Ṅwaneḑi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale1	14_Mutale2
MCB riparian trees	1900	110	100	120	125	180	110	85	100	100	100	100	105	110	90
	1960	110	100	110	110	140	110	85	100	100	100	100	100	110	95
	2000	100	100	100	100	100	100	95	100	100	100	100	100	100	100
MCB terrestrial trees	1900	90		110	85	115			125	125	90	90	120		
	1960	90		105	90	110			110	110	100	95	115		
	2000	100		100	100	100			100	100	100	100	110		

6.5 Ecospecifications, TPCs and recommendations for monitoring

The descriptive and numerical EcoSpecs and TPCs were written from the data collected to describe the following components of the riparian zone:

- Dominant vegetation cover in different zones.
- Key species; dominant plants that contribute to species richness, or rare, endemic and threatened plants.
- Invasion by exotic plants.
- Terrestrialisation, encroachment by terrestrial plants.
- General vegetation structure: proportion of non-woody (grasses, sedges and dicotyledonous forbs) and woody (shrubs and trees) plants, measured as % cover, density or population structure.

There are different types of riparian communities, e.g. grass dominated Highveld or mountain streams, tree and shrub dominated Lowveld or lowland rivers flowing through Bushveld, tall tree dominated (forest) rivers through gorges and on mountain slopes, or mixed vegetation e.g. reed and tree/shrub dominated rivers. There are also different kinds of plants in the different riparian zones, for example, the marginal zone often has many reeds and grasses while the Macro-Channel Bank (MCB) comprises trees and shrubs.

Key species were either dominant plants, based on observed abundance (cover or density), and whether they are rare, endemic or threatened (those with International Union for Conservation of Nature (IUCN) status other than Least Concern (LC) or Data Deficient (DD).

The relationship between aerial cover of exotic plants and the Ecological Category of the riparian zone **(Table 6.63**) was derived from data from the Crocodile and Sabie Rivers (in VEGRAI, Kleynhans *et al.* 2007). In these RQOs, exotic plants refers to perennial plants that persist year on year, i.e. shrubs, trees, cacti, climbers and so on. It excludes weedy annuals that grow, spread and die back in one year.

Table 6.63: Relationship between Ecological Category and % cover of exotic plants

Ecological Category	% Cover (Perennial exotics)
A	0
A/B	1 - 5
B	5 - 10
B/C	10 - 15
C	15 - 20
C/D	20 - 30
D	30 - 50
D/E	50 - 60
E	60 - 70
E/F	70 - 80
F	>80

Terrestrialisation is when non-riparian plants enter and grow in the riparian zone, in response to drying from reduced flow and flood frequency. **Table 6.64** outlines the hypothesis used to relate the degree of terrestrialisation to the Ecological Category. This hypothesis is based on the phenomenon that terrestrial species occur naturally in the riparian zone but are reduced in cover and abundance by increased flooding. Data of terrestrial:riparian ratios (on the Sabie River) showed a distinct reduction in terrestrial individuals with increasing exposure to flooding disturbance.

Table 6.64: Relationship between the cover of terrestrial plants in different riparian zones and Ecological Category (VEGRAI, Kleynhans *et al.* 2007)

Ecological Category	Marginal / Lower zones	Flood features / Upper zone	Upper zone / MCB
A	0	0	5 - 10
A/B	0	0	5 - 10
B	0	0	10 - 15
B/C	0	1 - 5	15 - 20
C	0	5 - 10	20 - 30
C/D	0	10 - 15	30 - 40
D	1 - 5	15 - 20	40 - 50
D/E	5 - 10	20 - 30	50 - 60
E	10 - 15	30 - 40	60 - 70
E/F	15 - 20	40 - 50	70 - 80
F	>20	>50	>80

General vegetation structure was characterised by relative proportions of riparian and terrestrial woody species, reeds and non-woody species, including grasses, sedges and dicotyledonous forbs, as well as unvegetated areas. Riparian zones will differ from one another by the proportion of different growth forms comprising each zone, measured as %cover or density (numbers of individuals) or population structure (diversity of cohorts of different age and size). When a riparian zone is infrequently flooded there is usually more woody cover on the banks and more reeds in the channel. Floods reset the community by removing woodies and reeds and making space for the growth of non-woody plants and

recruitment of woodies and reeds in new positions. The RQO assumes that if woody cover increases beyond a given value and remains high, the flooding regime has been changed *viz.* that large floods are smaller or less frequent or both.

6.6 Ecospecs and TPCs

6.6.1 1_Lephalala

The ecospecs and TPCs for 1_Lephalala are given in **Table 6.65**.

Table 6.65: 1_Lephalala vegetation EcoSpecs and TPCs (PES = C)

Component	EcoSpec	TPC
Aquatic zone		
Key Species	Potamogeton schweinfurthii and Stuckenia pectinatus must be present.	Potamogeton schweinfurthii or Stuckenia pectinatus are absent.
Marginal zone		
Dominant vegetation	Non-woody cover >= 50%.	Non-woody cover < 60%.
Key species	Miscanthus junceus and Ischaemum fasciculatum must be present.	Miscanthus junceus or Ischaemum fasciculatum are absent.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Terrestrial woody cover	No terrestrial woody plants.	Terrestrial woody plants present.
Indigenous woody cover	Woody cover <= 20%.	Woody cover > 10%.
Non-woody cover	Non-woody cover >= 50%.	Non-woody cover < 60%.
Reed cover	Reed cover <= 15%.	Reed cover > 15%.
Flood benches		
Dominant vegetation	Non-woody cover >= 50%.	Non-woody cover < 60%.
Key species	Miscanthus junceus and Ischaemum fasciculatum must be present.	Miscanthus junceus or Ischaemum fasciculatum are absent.
Exotic plants	Perennial exotic plants <= 20%.	Perennial exotic plants > 10%.
Terrestrial woody cover	No terrestrial woody plants.	Presence of terrestrial woody plants.
Indigenous woody cover	Woody cover <= 30%.	Woody cover > 20%.
Non-woody cover	Non-woody cover >= 50%.	Non-woody cover < 60%.
MCB		
Dominant vegetation	Woody cover >= 50%.	Woody cover < 60%.
Exotic plants	Perennial exotic plants <= 10%.	Perennial exotic plants > 5%.
Riparian zone		
PES	PES category = C with VEGRAI >= 62%.	VEGRAI < 65%.
Species richness	>= 20 indigenous species.	< 22 indigenous species.
Endemic riparian species	*Buxus macowanii (*SA endemic*)* and *Miscanthus junceus (*southern African endemic*)* must be present.	Buxus macowanii (SA endemic) or Miscanthus junceus (southern African endemic) are absent.

6.6.2 2_Rietfontein

The ecospecs and TPCs for 2_Rietfontein are given in **Table 6.66**.

Table 6.66: 2_Rietfontein vegetation EcoSpecs and TPCs (PES: A/B)

Component	EcoSpec	TPC
Marginal zone		
Dominant vegetation	Non-woody cover >= 60%.	Non-woody cover < 70%.
Key Species	Cyperus sexangularis and Juncus rigidus must be present.	Cyperus sexangularis or Juncus rigidus are absent.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Terrestrial woody cover	No terrestrial woody plants.	Terrestrial woody plants present.
Indigenous woody cover	Woody cover <= 10%.	Woody cover > 5%.
Non-woody cover	Non-woody cover >= 60%.	Non-woody cover < 70%.
Reed cover	No reeds.	Reeds are present.
Flood benches		
Dominant vegetation	Non-woody cover >=50%.	Non-woody cover < 60%.
Key species	Cyperus sexangularis and Juncus rigidus must be present.	Cyperus sexangularis or Juncus rigidus are absent.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Terrestrial woody cover	Terrestrial woody cover <= 20%.	Terrestrial woody cover > 10%.
Indigenous woody cover	Woody cover <= 50%.	Woody cover > 40%.
Non-woody cover	Non-woody cover >= 50%.	Non-woody cover < 60%.
MCB		
Dominant vegetation	Woody cover >= 70%.	Woody cover < 80%.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Riparian zone		
PES	PES categoty = A/B with VEGRAI >= 88%.	VEGRAI (4) < 90%.
Species richness	>= 15 indigenous species.	< 17 indigenous species.

6.6.3 3_Olifantspruit

The ecospecs and TPCs for 3_Olifantspruit are given in **Table 6.67**.

Table 6.67: 3_Olifantspruit vegetation EcoSpecs and TPCs (PES: D)

Component	EcoSpec	TPC
Marginal zone		
Dominant vegetation	Non-woody cover >= 20%.	Non-woody cover < 30%.
Key species	Phragmites australis, Juncus dregeanus and Juncus oxycarpus.	The absence of Phragmites australis, Juncus dregeanus or Juncus oxycarpus
Exotic plants	Perennial exotic plants <= 20%.	Perennial exotic plants > 10%.
Terrestrial woody cover	No terrestrial woody plants.	Terrestrial woody plants present.
Indigenous woody cover	Woody cover <= 10%.	Woody cover > 5%.
Non-woody cover	Non-woody cover >= 20%.	Non-woody cover < 30%.
Reed cover	Reed cover <= 30%.	Reed cover > 20%.
MCB		
Dominant vegetation	Woody cover >= 40%.	Woody cover < 50%.
Exotic plants	Perennial exotic plants <= 50%.	Perennial exotic plants > 40%.
Riparian zone		
PES	PES category = D with VEGRAI >= 42%.	VEGRAI < 48%.
Species richness	>= 20 indigenous species.	< 22 indigenous species.
Endemic riparian species	*Combretum erythrophyllum* (southern African endemic) must be present.	*Combretum erythrophyllum* (southern African endemic) is absent.

6.6.4 4_Mogalakwena1

The ecospecs and TPCs for Mogalakwena (Ri5) are listed in **Table 6.68**.

Table 6.68: 4_Mogalakwena1 vegetation EcoSpecs and TPCs (PES: C/D)

Component	EcoSpec	TPC
Marginal zone		
Dominant vegetation	Non-woody cover >= 60%.	Non-woody cover < 70%.
Key species	Juncus lomatophyllus and Phragmites australis must be present.	Juncus lomatophyllus or Phragmites australis are absent.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Terrestrial woody cover	No terrestrial woody plants.	Terrestrial woody plants present.
Indigenous woody cover	Woody cover <= 20%.	Woody cover > 10%.
Non-woody cover	Non-woody cover >= 60%.	Non-woody cover < 70%.
Reed cover	Reed cover <= 30%.	Reed cover > 20%.

Component	EcoSpec	TPC
Flood benches		
Dominant vegetation	Non-woody cover >= 70%.	Non-woody cover < 80%.
Key species	Flugea virosa, Agrostis lachnantha, Phragmites australis and Cynodon dactylon must be present.	Flugea virosa, Agrostis lachnantha, Phragmites australis or Cynodon dactylon are absent.
Exotic plants	Perennial exotic plants <= 10%.	Perennial exotic plants > 5%.
Terrestrial woody cover	Terrestrial woody cover <= 20%.	Terrestrial woody cover > 10%.
Indigenous woody cover	Woody cover <= 30%.	Woody cover > 20%.
Non-woody cover	Non-woody cover >= 50%.	Non-woody cover < 60%.
MCB		
Dominant vegetation	Woody cover >= 60%.	Woody cover < 70%.
Exotic plants	Perennial exotic plants <= 10%.	Perennial exotic plants > 5%.
Riparian zone		
PES	PES category = C/D with VEGRAI >= 58%.	VEGRAI < 60%.
Species richness	>= 15 indigenous species.	< 18 indigenous species.
Endemic riparian species	*Combretum erythrophyllum* (southern African endemic) must be present.	*Combretum erythrophyllum* (southern African endemic) is absent.

6.6.5 5_Mogalakwena2

The ecospecs and TPCs for 5_Mogalakwena are given in **Table 6.69**.

Table 6.69: 5_Mogalakwena2 vegetation EcoSpecs and TPCs (PES: C)

Component	EcoSpec	TPC
Marginal zone		
Dominant vegetation	Non-woody cover >= 65%.	Non-woody cover < 75%.
Key species	Juncus lomatophyllus, Cyperus digitatus, Ischaemum fasciculatum and Salix mucronata must be present.	Juncus lomatophyllus, Cyperus digitatus, Ischaemum fasciculatum or Salix mucronata are absent.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Terrestrial woody cover	No terrestrial woody plants.	Terrestrial woody plants present.
Indigenous woody cover	Woody cover <= 20%.	Woody cover > 10%.
Non-woody cover	Non-woody cover >= 65%.	Non-woody cover < 75%.
Reed cover	Reed cover <= 20%.	Reed cover > 10%.
Flood benches		
Dominant vegetation	Non-woody cover >= 70%.	Non-woody cover < 80%.
Key species	Cyperus digitatus and Gomphocarpus fruticosus must be present.	Cyperus digitatus or Gomphocarpus fruticosus are absent.

Component	EcoSpec	TPC
Exotic plants	Perennial exotic plants <= 20%.	Perennial exotic plants > 10%.
Terrestrial woody cover	Terrestrial woody cover <= 30%.	Terrestrial woody cover > 20%.
Indigenous woody cover	Woody cover <= 30%.	Woody cover > 20%.
Non-woody cover	Non-woody cover >= 40%.	Non-woody cover < 50%.
MCB		
Dominant vegetation	Woody cover >= 50%.	Woody cover < 60%.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Riparian zone		
PES	PES category of C with VEGRAI >= 62%.	VEGRAI < 65%.
Species richness	>= 20 indigenous species.	< 22 indigenous species.
Endemic riparian species	*Schotia brachypetala* (southern African endemic) must be present.	*Schotia brachypetala* (southern African endemic) is absent.
Threatened riparian species	3 nationally protected tree species: Apple Leaf (*Philenoptera violacea*), Leadwood (*Combretum imberbe*) and Camel Thorn (*Vachellia erioloba*) must be present.	Philenoptera violacea, Combretum imberbe or Vachellia erioloba are absent.

6.6.6 6_Kolope

The ecospecs and TPCs for Kolope are listed in **Table 6.70**.

Table 6.70: 6_Kolope vegetation EcoSpecs and TPCs (PES: C)

Component	EcoSpec	TPC
Flood benches		
Dominant vegetation	Non-woody cover >= 20%.	Non-woody cover < 30%.
Key species	Flueggea virosa and Croton megalobotrys must be present.	Flueggea virosa or Croton megalobotrys are absent.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Terrestrial woody cover	Terrestrial woody cover <= 15%.	Terrestrial woody cover > 10%.
MCB		
Dominant vegetation	Woody cover >= 35%	Woody cover < 45%.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Riparian zone		
PES	PES category = C with VEGRAI >= 62%.	VEGRAI (4) < 65%.
Species richness	>= 20 indigenous species.	< 22 indigenous species.
Threatened riparian species	2 nationally protected tree species: Apple Leaf (*Philenoptera violacea*) and Leadwood (*Combretum imberbe*) must be present.	Philenoptera violacea or Combretum imberbe are absent.

6.6.7 7_Sand

The ecospecs and TPCs for the Sand are given in **Table 6.71**.

Table 6.71: 7_Sand vegetation EcoSpecs and TPCs (PES: C)

Component	EcoSpec	TPC
Channel bed		
Dominant vegetation	Non-woody cover >= 5%.	Non-woody cover < 10%.
Key species	Cynodon dactylon must be present.	Cynodon dactylon is absent.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Terrestrial woody cover	No terrestrial woody plants.	Terrestrial woody plants present.
Reed cover	No reeds.	Reeds are present.
Flood benches		
Dominant vegetation	Non-woody cover >= 50%.	Non-woody cover < 60%.
Key species	Cynodon. dactylon, Sporobolus ioclados and Pennisetum macrourum must be present.	Cynodon. dactylon, Sporobolus ioclados or Pennisetum macrourum are absent.
Exotic plants	Perennial exotic plants <= 20%.	Perennial exotic plants > 10%.
Terrestrial woody cover	Terrestrial woody cover <= 10%.	Terrestrial woody cover > 5%.
Non-woody cover	Non-woody cover >= 50%.	Non-woody cover < 60%.
MCB		
Dominant vegetation	Woody and non-woody vegetation >= 60%	Woody and non-woody vegetation < 70%
Exotic plants	Perennial exotic plants <= 10%.	Perennial exotic plants > 5%.
Riparian zone		
PES	PES category = C with VEGRAI >= 62%.	VEGRAI < 65%.
Species richness	>= 15 indigenous species.	< 17 indigenous species.
Endemic riparian species	*Combretum erythrophyllum* (southern African endemic) must be present.	*Combretum erythrophyllum* (southern African endemic) is absent.

6.6.8 8_Nzhelele

The ecospecs and TPCs for 8_Nzhelele are given in **Table 6.72**.

Table 6.72: 8_Nzhelele vegetation EcoSpecs and TPCs (PES: B/C)

Component	EcoSpec	TPC
Marginal zone		
Dominant vegetation	Non-woody cover >= 20%.	Non-woody cover < 30%.
Key species	Juncus oxycarpus, Cyperus sexangularis, Phragmites mauritianus and Pluchea bojeri must be present.	Juncus oxycarpus, Cyperus sexangularis, Phragmites mauritianus or Pluchea bojeri are absent.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Terrestrial woody cover	No terrestrial woody plants.	Terrestrial woody plants present.
Non-woody cover	Woody cover <= 10%.	Woody cover > 5%.
Reed cover	Reed cover <= 10%.	Reed cover > 5%.
Flood benches		
Dominant vegetation	Non-woody cover >= 20%.	Non-woody cover < 30%.
Key species	*Pluchea bojeri* must be present.	Pluchea bojeri is absent.
Exotic plants	Perennial exotic plants <= 10%.	Perennial exotic plants > 5%.
Terrestrial woody cover	Terrestrial woody cover <= 10%.	Terrestrial woody cover > 5%.
Non-woody cover	Non-woody cover >= 10%.	Non-woody cover < 20%.
MCB		
Dominant vegetation	Woody cover >= 50%.	Woody cover < 60%.
Exotic plants	Perennial exotic plants <= 10%.	Perennial exotic plants > 5%.
Riparian zone		
PES	PES category = B/C with VEGRAI >= 78%.	VEGRAI (4) < 80%.
Species richness	>= 25 indigenous species.	< 27 indigenous species.
Threatened riparian species	1 nationally protected tree species: Apple Leaf (*Philenoptera violacea*) must be present.	Philenoptera violacea is absent.

6.6.9 9_Ṅwaneḍi

The ecospecs and TPCs for 9_Ṅwaneḍi are given in **Table 6.73**.

Table 6.73: 9_Ṅwaneḍi vegetation EcoSpecs and TPCs (PES: C)

Component	EcoSpec	TPC
Marginal zone		
Dominant vegetation	Non-woody cover >= 10%.	Non-woody cover < 15%.
Key species	Commelina diffusa must be present.	Commelina diffusa is absent.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Terrestrial woody cover	No terrestrial woody plants.	Terrestrial woody plants present.
Reed cover	No reeds.	Reeds are present.
Flood benches		
Dominant vegetation	Non-woody cover >= 60%.	Non-woody cover < 70%.
Key species	Ficus sycomorus, Breonaria salicina, Combretum erythrophyllum and Faidherbia albida must be present.	Ficus sycomorus, Breonaria salicina, Combretum erythrophyllum or Faidherbia albida are absent.
Exotic plants	Perennial exotic plants <= 10%.	Perennial exotic plants > 5%.
Terrestrial woody cover	Terrestrial woody cover <= 15%.	Terrestrial woody cover > 10%.
MCB		
Dominant vegetation	Woody cover >= 70%.	Woody cover < 80%.
Exotic plants	Perennial exotic plants <= 10%.	Perennial exotic plants > 5%.
Riparian zone		
PES	PES category = C with VEGRAI >= 62%.	VEGRAI (4) < 65%.
Species richness	>= 20 indigenous species.	< 22 indigenous species.
Endemic riparian species	*Buxus macowanii (*SA endemic*)* and *Schotia brachypetala (*southern African endemic*)* must be present.	Buxus macowanii (SA endemic) or Schotia brachypetala (southern African endemic) are absent.
Threatened riparian species	1 nationally protected tree species: Matumi (*Breonadia salicina* must be present.	Breonadia salicina is absent.

6.6.10 10_Latonyanda

The ecospecs and TPCs for 10_Latonyanda are given in **Table 6.74**.

Table 6.74: 10_Latonyanda vegetation EcoSpecs and TPCs (PES: C/D)

Component	EcoSpec	TPC
Channel		
Dominant vegetation	Non-woody cover >= 20%.	Non-woody cover < 30%.
Key species	Cyclosorus interruptus, Commelina diffusa and Isolepis cernua must be present.	Cyclosorus interruptus, Commelina diffusa or Isolepis cernua are absent.
Exoti plants	Perennial exotic plants <= 10%.	Perennial exotic plants > 5%.
Terrestrial woody cover	Terrestrial woody cover <= 20%.	Terrestrial woody cover > 10%.
Reed cover	No reeds.	Reeds are present.
MCB		
Dominant vegetation	Woody cover >= 60%.	Woody cover < 70%.
Exotic plants	Perennial exotic plants <= 10%.	Perennial exotic plants > 5%.
Riparian zone		
PES	PES category = C/D with VEGRAI >= 58%.	VEGRAI (4) < 60%.
Species richness	>= 15 indigenous species.	< 17 indigenous species.
Endemic riparian species	*Combretum erythrophyllum* (southern African endemic) must be present.	*Combretum erythrophyllum* (southern African endemic) is absent.

6.6.11 11_Mutshindudi

The ecospecs and TPCs for 11_Mutshindudi are given in **Table 6.75**.

Table 6.75: 11_Mutshindudi vegetation EcoSpecs and TPCs (PES: C)

Component	EcoSpec	TPC
Marginal zone		
Dominant vegetation	A mix of woody and non-woody plants.	Dominance by either woody or non-woody plants.
Key species	Breonadia salicina, Cyclosorus interruptus, Phragmites mauritianus, Salix mucronata, Cyperus alopecuroides, Cyperus eragrostis and Juncus lomatophyllus must be present.	Breonadia salicina, Cyclosorus interruptus, Phragmites mauritianus, Salix mucronata, Cyperus alopecuroides, Cyperus eragrostis or Juncus lomatophyllus are absent.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Terrestrial woody cover	No terrestrial woody plants.	Terrestrial woody plants present.
Indigenous woody cover	Woody cover <= 20%.	Woody cover > 10%.
Non-woody cover	Non-woody cover >= 30%.	Non-woody cover < 40%.
Reed cover	Reed cover <= 25%.	Reed cover > 15%.
Flood benches		
Dominant vegetation	A mix of woody and non-woody plants.	Dominance by either woody or non-woody plants.
Key species	Breonadia salicina, Phragmites mauritianus, Salix mucronata, and Ficus sycomorus must be present.	Breonadia salicina, Phragmites mauritianus, Salix mucronata, or Ficus sycomorus are absent.
Exotic plants	Perennial exotic plants <= 15%.	Perennial exotic plants > 10%.
Terrestrial woody cover	Terrestrial woody cover <= 15%.	Terrestrial woody cover > 10%.
Indigenous woody cover	Woody cover <= 15%.	Woody cover > 10%.
Non-woody cover	Non-woody cover >= 15%.	Non-woody cover < 25%.
MCB		
Dominant vegetation	Woody cover >= 20%.	Woody cover < 30%.
Exotic plants	Perennial exotic plants <= 20%.	Perennial exotic plants > 10%.
Riparian zone		
PES	PES category = C with VEGRAI >= 62%.	VEGRAI < 65%.
Species richness	>= 25 indigenous species.	< 27 indigenous species.
Threatened riparian species	2 nationally protected tree species: Apple Leaf (*Philenoptera violacea*) and Matumi (*Breonadia salicina*) must be present.	Philenoptera violacea or Breonadia salicina are absent.

6.6.12 12_Luvuvhu

The ecospecs and TPCs for 12_Luvuvhu are given in **Table 6.76**.

Table 6.76: 12_Luvuvhu vegetation EcoSpecs and TPCs (PES: C)

Component	EcoSpec	TPC
Marginal zone		
Dominant vegetation	Non-woody cover >= 50%.	Non-woody cover < 60%.
Key species	Phragmites mauritianus, Breonadia salicina and Ficus caprefolia must be present.	Phragmites mauritianus, Breonadia salicina or Ficus caprefolia are absent.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Terrestrial woody cover	No terrestrial woody plants.	Terrestrial woody plants present.
Indigenous woody cover	Woody cover <= 25%.	Woody cover > 15%.
Non-woody cover	Non-woody cover >= 50%.	Non-woody cover < 60%.
Reed cover	Reed cover <= 65%.	Reed cover > 55%.
Flood bench		
Dominant vegetation	A mix of woody and non-woody plants.	Dominance by either woody or non-woody plants.
Key species	Phragmites mauritianus, Ludwigia octovalvis, Pluchea dioscoridis, Phyllanthus reticulatus, Flueggea virosa, Ficus sycomorus and Combretum erythrophyllum must be present.	Phragmites mauritianus, Ludwigia octovalvis, Pluchea dioscoridis, Phyllanthus reticulatus, Flueggea virosa, Ficus sycomorus or Combretum erythrophyllum are absent.
Exotic plants	Perennial exotic plants <= 15%.	Perennial exotic plants > 10%.
Terrestrial woody cover	Terrestrial woody cover <= 15%.	Terrestrial woody cover > 10%.
Indigenous woody cover	Woody cover <= 15%.	Woody cover > 10%.
Non-woody cover	Non-woody cover >= 15%.	Non-woody cover < 25%.
MCB		
Dominant vegetation	Woody cover >= 50%.	Woody cover < 60%.
Exotic plants	Perennial exotic plants <= 15%.	Perennial exotic plants > 10%.
Riparian zone		
PES	PES category = C with VEGRAI >= 62%.	VEGRAI < 65%.
Species richness	>= 33 indigenous species.	< 35 indigenous species.
Endemic riparian species	*Combretum erythrophyllum* (southern African endemic) must be present.	Combretum erythrophyllum is absent.
Threatened riparian species	2 nationally protected tree species: Apple Leaf (*Philenoptera violacea*) and Matumi (*Breonadia salicina*) must be present.	Philenoptera violacea or Breonadia salicina are absent.

6.6.13 13_Mutale1

The ecospecs and TPCs for 13_Mutale 1 are given in **Table 6.77**.

Table 6.77: 13_Mutale1 vegetation EcoSpecs and TPCs (PES: B/C)

Component	EcoSpec	TPC
Aquatic zone		
Key species	Potamogeton schweinfurthii, Stuckenia pectinatus and Nymphoides thunbergiana must be present.	Potamogeton schweinfurthii, Stuckenia pectinatus or Nymphoides thunbergiana are absent.
Marginal zone		
Dominant vegetation	Non-woody cover >= 70%.	Non-woody cover < 80%.
Key species	Ischaemum fasciculatum, Juncus lomatophyllus, Phragmites mauritianus, Breonadia salicina and Gomphostigma virgatum must be present.	Ischaemum fasciculatum, Juncus lomatophyllus, Phragmites mauritianus, Breonadia salicina or Gomphostigma virgatum are absent.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Terrestrial woody cover	No terrestrial woody plants.	Terrestrial woody plants present.
Indigenous woody cover	Woody cover <= 15%.	Woody cover > 5%.
Non-woody cover	Non-woody cover >= 70%.	Non-woody cover < 80%.
Reed cover	Reed cover <= 30%.	Reed cover > 20%.
Flood benches		
Dominant vegetation	A mix of woody and non-woody plants.	Dominance by either woody or non-woody plants.
Key species	Syzygium cordatum, Syzygium guineense, Combretum erythrophyllum, Miscanthus junceus, Juncus lomatophyllus, Juncus oxycarpus, Schoenoplectus brachyceras and Ischaemum fasciculatum must be present.	Syzygium cordatum, Syzygium guineense, Combretum erythrophyllum, Miscanthus junceus, Juncus lomatophyllus, Juncus oxycarpus, Schoenoplectus brachyceras or Ischaemum fasciculatum are absent.
Exotic plants	Perennial exotic plants <= 15%.	Perennial exotic plants > 10%.
Terrestrial woody cover	Terrestrial woody cover <= 15%.	Terrestrial woody cover > 5%.
Indigenous woody cover	Woody cover <= 20%.	Woody cover > 10%.
Non-woody cover	Non-woody cover >= 50%.	Non-woody cover < 60%.
Seep wetlands		
Dominant vegetation	Non-woody with some aquatic plants >= 50%.	Non-woody with some aquatic plants < 60%.
Key species	Juncus lomatophyllus, Juncus oxycarpus, Cyperus dives, Schoenoplectus brachyceras, Ischaemum fasciculatum, Crinum macowanii, Potamogeton schweinfurthii, Nymphaea nouchali and Nymphoides thunbergiana must be present.	Juncus lomatophyllus, Juncus oxycarpus, Cyperus dives, Schoenoplectus brachyceras, Ischaemum fasciculatum, Crinum macowanii, Potamogeton schweinfurthii, Nymphaea nouchali or Nymphoides thunbergiana are absent.
MCB		
Dominant vegetation	Woody cover >= 50%.	Woody cover < 60%.
Exotic plants	Perennial exotic plants <= 15%.	Perennial exotic plants > 5%.
Riparian zone		
PES	PES category = B/C with VEGRAI >= 78%.	VEGRAI < 80%.

Component	EcoSpec	TPC
Species richness	>= 33 indigenous species.	< 35 indigenous species.
Endemic riparian species	*Combretum erythrophyllum* and *Miscanthus junceus* (southern African endemics) must be present.	Combretum erythrophyllum or Miscanthus junceus (southern African endemics) are absent.

6.6.14 14_Mutale2

The ecospecs and TPCs for 14_Mutale2 are given in **Table 6.78**.

Table 6.78: 14_Mutale vegetation EcoSpecs and TPCs (PES: B)

Component	EcoSpec	TPC
Marginal zone		
Dominant vegetation	Non-woody cover >= 60%.	Non-woody cover < 70%.
Key species	Phragmites mauritianus and Breonadia salicina must be present.	Phragmites mauritianus or Breonadia salicina are absent.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Terrestrial woody cover	No terrestrial woody plants.	Terrestrial woody plants present.
Indigenous woody cover	Woody cover <= 15%.	Woody cover > 5%.
Non-woody cover	Non-woody cover >= 50%.	Non-woody cover < 60%.
Flood Bench		
Dominant vegetation	A mix of woody and non-woody plants.	Dominance by either woody or non-woody plants.
Key species	Faidherbia albida must be present.	Faidherbia albida is absent.
Exotic plants	Perennial exotic plants <= 10%.	Perennial exotic plants > 5%.
Terrestrial woody cover	Terrestrial woody cover <= 15%.	Terrestrial woody cover > 5%.
Indigenous woody cover	Woody cover <= 20%.	Woody cover > 10%.
Non-woody cover	Non-woody cover >= 20%	Non-woody cover < 30%.
MCB		
Dominant vegetation	Woody cover >= 50%.	Woody cover < 60%.
Exotic plants	No perennial exotic plants.	Perennial exotic plants present.
Riparian zone		
PES	PES category = B with VEGRAI >= 82%.	VEGRAI < 84%.
Species richness	>= 33 indigenous species.	< 35 indigenous species.
Threatened riparian species	3 nationally protected tree species: Apple Leaf (*Philenoptera violacea*) Leadwood (*Combretum imberbe*) and Matumi (*Breonadia salicina*) must be present.	Philenoptera violacea, Combretum imberbe or Breonadia salicina are absent.

6.6.15 Recommendations

The following recommendations should be considered:

- Riparian vegetation should be monitored from late October to early November before high flows have started and new leaves and flowers have emerged for easier identification.
- Monitoring should be done annually, preferably in early spring when flows are still low, and vegetation is sprouting.
- Fixed point photographs of each zone assessed must be taken.
- Each time new satellite coverage becomes available images for each site, and at different elevations should be stored for each site. This will require regular checks of coverage dates in Google Earth ©.

7 AQUATIC MACROINVERTEBRATES

7.1 Introduction

The main objective of the macroinvertebrate study was to identify the relationship between macroinvertebrates and flow level changes, and to predict what impacts, if any, will occur with changes to the present-day flow regimes.

7.1.1 Assumptions and limitations

Macroinvertebrate data were collected during August 2022 and May 2023. Two of the sites are non-perennial (6_Kolope and 7_Sand) and no surface water was present at the time of assessment, so no samples were collected. There is also no historic data available for these two sites. The DRIFT response curves for these two sites were therefore modelled using information from other similar non-perennial rivers.

2_Rietfontein is also an unusual freshwater ecosystem that is spring-fed. The site was assessed to determine what taxa occur in the system, given the available instream habitat at the time of assessment. Important to note is that SASS5 was not used for assessment purposes because this drainage line is a spring-fed/wetland-type system. No historic data was available for this site, so data collected at the site was used for input to the DRIFT model.

7.2 EWR sites with a focus on aquatic macroinvertebrates

7.2.1 Catchment description

Aquatic macroinvertebrates have preferred habitats, defined by instream habitat, flow, and physico-chemical water quality parameters that differ between rivers due to differences in climate, topography, underlying geology and the flow of sediment and water. Ecoregions (Kleynhans *et al.* 2007) and geomorphological zones (Rowntree *et al.* 2001) broadly define changes in habitat across the study area. These were summarised in the Status Quo Report (DWS 2022). For example, taxa occurring in Mountain Headwater Streams in the Soutpansberg Ecoregion, will be very different to macroinvertebrate taxa occurring in in the Lower Foothills of the Lowveld Ecoregion, as an example. Macroinvertebrate taxa that are important in the study area, include the Paleomonidae (Prawns) that use the Lowveld Rivers as migration corridors for their survival, the Oligoneuridae (Brushlegged Mayflies) that occur in some of the rivers and Prosopistomatidae (Water specs) and Perlidae (Stoneflies). Stoneflies are very sensitive to water quality and changes in flow. Taxa expected to occur naturally in the study area are listed in **Table 7.1.**

Table 7.1: Macroinvertebrates expected in undisturbed EWR sites (A = 1-10, B = 11-100 , C = 100 – 1000, D = > 1000 individuals)

Taxon	1_Lephalala	3_Olifantspruit	4_Mogalakwena1	5_Mogalakwena2	8_Nzhelele	9_Ṅwaneḍi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale1	14_Mutale2
Porifera	A		A			A	A	A	A	A	A
Coelenterata											
Turbellaria	A	A	A		A	A	A	A	A	A	A
Oligochaeta	A	A	A	A	A	A	A	A	A	A	A
Hirudinea	A	A	A	A	A	A	A	A	A	A	A
Amphipoda											
Potamonautidae	A	A	A	A	A	A	A	A	A	A	A
Atyidae	A	A	A	B	A	B	B	A	B	A	B
Palaemonidae					A	A		A	A	A	A
Hydracarina	A	A	A	A	A	A	A	A	A	A	A
Perlidae	A		A		A	A	A	A	B	A	A
Baetidae 1sp											
Baetidae 2spp											
Baetidae >2spp	B	B	B	B	B	B	B	B	B	B	B
Caenidae	A	B	A	B	B	A	A	A	B	A	A
Ephemeridae											
Heptageniidae	A		A	A	A	B	B	A	B	A	A
Leptophlebiidae	A	A	A	A	B	B	B	B	B	B	A
Oligoneuridae	A		A	A	A	A	A	A	A	A	A
Polymitarcyidae	A						A	A	A	A	
Prosopistomatidae											
Tricorythidae	A		A	A	A	A	B	A	A	A	A
Calopterygidae	A					A	A	A	A	A	A
Chlorocyphidae	A	A	A		A	A	A	A	A	A	A
Chlorolestidae						A	A	A	A	A	A
Coenagrionidae	A	B	A	A	A	A	A	A	B	A	A
Lestidae	A	A		A	A	A	A	A	A	A	
Platycnemidae	A		A	A	A	A	A	A	A	A	A
Protoneuridae						A		A		A	A
Aeshnidae	A	A	A	A	A	A	A	A	A	A	A
Corduliidae	A	A	A	A	A	A	A	A	A	A	A
Gomphidae	A	A	B	B	B	B	B	A	B	A	B
Libellulidae	A	A	B	A	A	A	A	A	B	A	B
Pyralidae	A					A	A	A	A	A	A
Belostomatidae	A	B	A	A	A	A	A	A	A	A	A
Corixidae	A	B	A	A	A	A	A	A	A	A	A
Gerridae	A	B	A	A	A	A	B	A	B	A	A
Hydrometridae	A	A	A	A	A	A	A	A	A	A	A
Naucoridae	A	A	A	A	A	B	A	A	A	A	A
Nepidae	A	A	A	A	A	A	A	A	A	A	A
Notonectidae	A	A	A	A	A	A	A	A	A	A	A
Pleidae	A	A	A	A	A	A	A	A	A	A	A
Veliidae	A	A	B	B	A	B	B	A	B	B	B
Corydalidae											
Sialidae											
Dipseudopsidae	A						A				
Ecnomidae	A	A	A		A	A	A	A	A	A	A
Hydropsychidae 1sp											
Hydropsychidae 2spp											
Hydropsychidae >2spp	B	B	B	B	B	B	B	B	B	B	B
Philopotamidae	A	A	A	A	A	A	A	A	A	A	A
Polycentropodidae									A		

Taxon	1_Lephalala	3_Olifantspruit	4_Mogalakwena1	5_Mogalakwena2	8_Nzhelele	9_Ṅwaneḍi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale1	14_Mutale2
Psychomyiidae									A		
Calamoceratidae							A	A		A	
Hydroptilidae	A	A	A	A	A	A	A	A	B	A	A
Lepidostomatidae	A					A	A	A	A	A	A
Leptoceridae	A	A	A	A	A	A	B	A	A	A	A
Dytiscidae	A	A	A	A	A	A	A	A	A	A	A
Elmidae	A	A	A	A	A	A	A	A	A	A	A
Gyrinidae	A	B	B	B	B	A	B	A	B	A	B
Haliplidae		A			A	A		A	A	A	A
Helodidae		A	A		A		A	A	A	A	
Hydraenidae	A	A	A	A	A	A	A	A	A	A	A
Hydrophilidae	A	A	A	A	A	A	A	A	A	A	A
Limnichidae											
Psephenidae		A				A	A	A	A	A	A
Athericidae	A				A	A	A	A	A	A	A
Blepharoceridae											
Ceratopogonidae	A	A	A	A	A	A	A	A	A	A	A
Chironomidae	A	B	A	B	B	B	B	B	B	B	B
Culicidae	A	A	A	A	A	A	A	A	A	A	A
Dixidae	A	A	A				A	A		A	A
Empididae	A							A	A	A	
Ephydridae									A		
Muscidae	A	A	A	A	A	A	A		A	A	A
Psychodidae											
Simuliidae	B	B	B	B	B	B	B	B	B	B	B
Syrphidae											
Tabanidae	A	A	A	A	A	A	A	A	A	A	A
Tipulidae	A	A	A	A	A	A	A	A	A	A	A
Ancylidae	A	A		A	A	A	A	A	A	A	A
Bulinae	A	A		A			A		A		
Hydrobiidae											
Lymnaeidae	A	B	A	A	A	A	A	A	A	A	A
Physidae			*						*		*
Planorbinae	A	A	A	A	A	A	A	A	B	A	A
Thiaridae	A		A	A	A	A	A	A	A	A	A
Viviparidae											
Corbiculidae	A	A	A	A	A	A	A	A	B	A	A
Sphaeridae		A		A	A	A	A	A	A	A	A
Unionidae				A	A				A		

7.2.2 Data collection and analysis

Macroinvertebrates were sampled during August 2022 and May 2023 using the South African Scoring System Version 5.0 (SASS5 Dickens and Graham 2002), a rapid biomonitoring tool for perennial rivers that uses pre-determined sensitivity weightings for different macroinvertebrate taxa to give an indication of water quality impairment and overall river integrity.

Temperature, pH, dissolved oxygen (mg/l and percentage) and electrical conductivity were measured with a hand-held meter and water clarity, turbidity, flow and other observations relevant to assess habitat quality for macroinvertebrates were made.

The MIRAI (Macroinvertebrate Response Assessment Index) was used to analyse the SASS5 data collected (Thirion 2007, Thirion 2016). Present day and relevant historic data for sites within the same Ecoregion Level II and geomorphological zone were sourced. The MIRAI was developed to provide a habitat-based cause-and-effect foundation to interpret the deviation of the macroinvertebrate assemblage from reference condition (Thirion 2007, Thirion 2016). The MIRAI generates an Ecological Category for macroinvertebrates by integrating the ecological requirements of an assemblage and relating this to modified flow, instream habitat and water quality conditions. An EC was derived per site. Reference conditions for this project were set using historic SASS5 data, the reference taxa generator within the MIRAI, as well as specialist judgement.

The raw data collected in August 2022 are summarised in **Table 7.2** and those collected in May 2023 in **Table 7.3**.

Table 7.2: Taxa observed during August 2022 (A = 1-10, B = 11-100 , C = 100 – 1000, D = > 1000 individuals)

Taxon	1_Lephalala	2_Rietfontein*	3_Olifantspruit	4_Mogalakwena 1	5_Mogalakwena 2	8_Nzhelele	9_Ṅwaneḍi	10_Latonyanda *	11_Mutshindudi	12_Luvuvhu	13_Mutale 1	14_Mutale 2
Porifera	A						A					
Coelenterata												
Turbellaria			1				A					
Oligochaeta			A			A	1		1	A		
Hirudinea						A						
Amphipoda												
Potamonautidae	A		A	A	1	A	A		A	A	A	
Atyidae				1		1	1		1	B		
Palaemonidae												A
Hydracarina	A									1	A	1
Notonemouridae												
Perlidae	A								B	B	1	1
Baetidae 1sp												
Baetidae 2spp												
Baetidae >2spp	B		B	B	B	B	B		B	B	B	B
Caenidae			B	A	B	B	A		B	B	A	A
Ephemeridae												
Heptageniidae	A				1	A	B		B	B	A	B
Leptophlebiidae			B	B	B	B	A		B	B	B	B
Oligoneuridae												
Polymitarcyidae												
Prosopistomatidae												
Telagonodidae												
Tricorythidae					1							
Calopterygidae												
Chlorocyphidae	1		A	1		A						
Chlorolestidae												
Coenagrionidae	B		B	A	1	A	A		1	A	B	B
Lestidae												
Platycnemidae												

Taxon	1_Lephalala	2_Rietfontein*	3_Olifantspruit	4_Mogalakwena 1	5_Mogalakwena 2	8_Nzhelele	9_Ṅwaneḍi	10_Latonyanda *	11_Mutshindudi	12_Luvuvhu	13_Mutale 1	14_Mutale 2
Protoneuridae												
Aeshnidae												
Corduliidae												A
Gomphidae	A		B	A	A	A	A		A	B		B
Libellulidae	A		A	1		B	A		A	B	A	B
Pyralidae										1		
Belostomatidae	A						A				1	B
Corixidae	A				1				A		A	
Gerridae			1		A	1	A					
Hydrometridae												
Naucoridae	1		1	A	A	A						
Nepidae	1					1			1			
Notonectidae						1			1			
Pleidae									1			
Veliidae	B		A	B	B	B	B		A	B	B	B
Corydalidae												
Sialidae												
Dipseudopsidae												
Ecnomidae					1							
Hydropsychidae 1sp							A				A	
Hydropsychidae 2spp	A				B	A						
Hydropsychidae >2spp			B	B					A	A		B
Philopotamidae	A		B	A					1			B
Polycentropodidae												
Psychomyiidae												
Barbarochthonidae												
Calamoceratidae												
Glossosomatidae												
Hydroptilidae				1		B	1				A	
Hydrosalpingidae												
Lepidostomatidae												
Leptoceridae	B		B	A					A	B	A	A
Petrothrincidae												
Pisuliidae												
Sericostomatidae												
Dytiscidae	A		A		A	A			A			A
Elmidae	A					A				1	1	A
Gyrinidae	B		B		A		B			B	A	C
Haliplidae												
Helodidae												
Hydraenidae												
Hydrophilidae												1
Limnichidae												
Psephenidae			1							1		
Athericidae							A		A	A		
Blepharoceridae												
Ceratopogonidae	1		1	1	1	A			A	A	A	A

Taxon	1_Lephalala	2_Rietfontein*	3_Olifantspruit	4_Mogalakwena 1	5_Mogalakwena 2	8_Nzhelele	9_Ṅwaneḍi	10_Latonyanda *	11_Mutshindudi	12_Luvuvhu	13_Mutale 1	14_Mutale 2
Chironomidae	A		B	A	A	A	1		B	B	B	B
Culicidae			A		1							1
Dixidae			1									
Empididae												
Ephydridae												
Muscidae					1							
Psychodidae												
Simuliidae	A		B	B	B	B	B		1	B	1	A
Syrphidae												
Tabanidae			1	A	A	A	A		A	1	A	A
Tipulidae	1								A	A		
Ancylidae										A	1	
Bulinae												
Hydrobiidae												
Lymnaeidae												
Physidae												
Planorbinae											A	A
Thiaridae					A	C	B		B	A		B
Viviparidae												
Corbiculidae					1	B			1	B		A
Sphaeridae												
Unionidae						1						
SASS Total Score	155		151	125	133	158	127		169	190	137	184
No. of Taxa	25		25	19	24	28	23		28	28	23	28
ASPT	6,2		6,0	6,6	5,5	5,6	5,5		6,0	6,8	6,0	6,6
	Abundances:											
	A = 1 - 10 individuals											
	B = 11 - 100 individuals											
	C = 101 - 1000 individuals											
* No sample												
(Site 2_Rietfontein is not suitable for SASS, it is situated downstream of a spring)												

Table 7.3: The taxa observed during May 2023 (A = 1-10, B = 11-100 individuals)

Taxon	1_Lephalala	2_Rietfontein *	3_Olifantspruit	4_Mogalakwena 1	5_Mogalakwena 2	8_Nzhelele	9_Ṅwaneḍi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale 1	14_Mutale 2
Porifera									A			
Coelenterata												
Turbellaria							1					1
Oligochaeta			A	1	A	A	1	A		1		A
Hirudinea							1					
Amphipoda												
Potamonautidae	A		B	A	1	A	A	A	A	A	1	
Atyidae			A	B	A	A	A	A		1		
Paleomonidae												
Hydracarina		1				1		A		1	A	A
Notonemouridae												
Perlidae								A	B	B	A	1
Baetidae 1sp												
Baetidae 2spp	B			B	A		A					
Baetidae >2spp		B	B			B		B	B	B	B	B
Caenidae		1	1	A	A	B	1	A	A	A		1
Ephemeridae												
Heptageniidae	A			A		1	A	A	B	B	A	B
Leptophlebiidae	A		A	A	A	B	A	A	B	1	A	B
Oligoneuridae	A			A		A			A	A	A	1
Polymitarcyidae												
Prosopistomatidae												
Telagonodidae												
Tricorythidae				A		1		B				1
Calopterygidae												
Chlorocyphidae			A				1	A				
Chlorolestidae												
Coenagrionidae	A	B	A	A	1	1	1	A	A	A		A
Lestidae												
Platycnemidae												
Protoneuridae												
Aeshnidae		A										
Corduliidae			1							A		
Gomphidae	A	B	A	A	A	A	B	B	B	B		B
Libellulidae	A	A	A			A	A	A	B	B	A	A
Pyralidae												
Belostomatidae							1					
Corixidae	A				A					1		

Taxon	1_Lephalala	2_Rietfontein *	3_Olifantspruit	4_Mogalakwena 1	5_Mogalakwena 2	8_Nzhelele	9_Ṅwaneḍi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale 1	14_Mutale 2
Gerridae	A	A	B					B	A			
Hydrometridae			A									
Naucoridae	1	A	A	B	1	1			A			A
Nepidae		A		1								
Notonectidae		B										1
Pleidae												
Veliidae	B	A	B		A	B		B	A		A	A
Corydalidae												
Sialidae												
Dipseudopsidae												
Ecnomidae												
Hydropsychidae 1sp						A	A			A		A
Hydropsychidae 2spp	A			A	A							
Hydropsychidae >2spp			A					B	B		A	
Philopotamidae				A		A	1	A	A	A	A	A
Polycentropodidae												
Psychomyiidae												
Barbarochthonidae												
Calamoceratidae												
Glossosomatidae												
Hydroptilidae					1							
Hydrosalpingidae												
Lepidostomatidae												
Leptoceridae	A		1				A	A	A	A	B	A
Petrothrincidae												
Pisuliidae												
Sericostomatidae												
Dytiscidae		B						A	1	A	1	
Elmidae	1					A			A	A		
Gyrinidae			B			B		B	A	B		C
Haliplidae												
Helodidae												
Hydraenidae												
Hydrophilidae			1			1						
Limnichidae												
Psephenidae								A		B	A	
Athericidae							A	A	A			1
Blepharoceridae												
Ceratopogonidae	A				1	1		A		A	A	

Taxon	1_Lephalala	2_Rietfontein *	3_Olifantspruit	4_Mogalakwena 1	5_Mogalakwena 2	8_Nzhelele	9_Ṅwanedi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale 1	14_Mutale 2
Chironomidae	A	A	A	1	A	A		A	A	B	B	A
Culicidae												
Dixidae												
Empididae												
Ephydridae												
Muscidae												
Psychodidae												
Simuliidae	A	1		A	A			A		A	A	
Syrphidae												
Tabanidae	A		A		A	A	A	A		A	A	A
Tipulidae	1		1					A	A			
Ancylidae			1									
Bulinae												
Hydrobiidae												
Lymnaeidae												
Physidae												
Planorbinae				1								
Thiaridae					B	D	A		B	B	1	1
Viviparidae												
Corbiculidae						A	1			A		
Sphaeridae												
Unionidae												
SASS Total Score	122		140	116	90	162	122	183	94	185	144	162
No. of Taxa	20		23	18	18	25	21	27	13	28	19	24
ASPT	6,1		6,1	6,4	5	6,5	5,8	6,8	7,2	6,6	7,6	6,8
	Abundances:											
	A = 1 - 10 individuals											
	B = 11 - 100 individuals											
	C = 101 - 1000 individuals											
* No sample - not suitable for SASS, site is downstream of a spring												

7.2.3 Description of sites

7.2.3.1 1_Lephalala

This site is situated on the Lephalala River in Waterberg Ecoregion 6.01 (Kleynhans et al. 2007a*)* in the Lower Foothills (Rowntree & Wadeson 1999). There was a good quantity and quality of cobble/boulder habitat, with stones in- and out-of-current present. There was very little GSM, marginal vegetation in- and out- of-current and some aquatic vegetation present (**Figure 7.1**). During August 2022 25 taxa were recorded (**Table 7.2**), with a SASS Total score of 155 and a corresponding ASPT of 6.2. During May 2023, 20 taxa were identified (**Table 7.3**), a Total SASS score of 122 and ASPT of 6.1 were recorded. The Present Ecological Status was a **B/C** Category, being largely natural to moderately modified (**Table 7.4**). Water quality was the most impacted driver metric, followed by instream habitat and lastly flow modification. Nutrient levels were higher than normal, with instream sediment and algae present at the time of the assessments. Taxa characterising the site included Perlidae, Heptageniidae, Oligoneuridae, Chlorocyphidae, Philopotamidae and Elmidae.



Upstream view



Downstream view

Figure 7.1: Aquatic habitat for macroinvertebrates at 1_Lephalala

Table 7.4: Results of the MIRAI assessment for 1_Lephalala

MIRAI		CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE	RANK	%WEIGHT
FLOW MODIFICATION	FM	82.3	0.32	26.4	2	95
HABITAT	H	81.6	0.33	27.6	1	100
WATER QUALITY	WQ	73.7	0.33	24.9	1	100
CONNECTIVITY & SEASONALITY	CS	100.0	0.00	0	3	0
INVERTEBRATE SCORE (%)				79.1		
INVERTEBRATE CATEGORY				**B/C**		

7.2.3.2 2_Rietfontein

2_Rietfontein in the Limpopo Plain 1.02 Ecoregion, is spring-fed and is characterized by standing pools with sandy benthic or rocky habitat present. Marginal vegetation consisting mainly of grass and sedges was also present (**Figure 7.2**). Since this river is not a perennially flowing river there was no SASS assessment done, nor a MIRAI assessment for ecological condition. Taxa present included Baetidae, Caenidae, Coenagrionidae, Gomphidae, Libellulidae, Notonectidae, Dytiscide and Simuliidae.

	
Upstream view	Downstream view

Figure 7.2: Aquatic habitat for macroinvertebrates at 2_Rietfontein

7.2.3.3 3_Olifantspruit

3_Olifantspruit is in the Bushveld Basin 8.01 Ecoregion in the Lower Foothills. There was a section of riffles and runs dominated by stones-in and out-of-current, with some GSM and marginal vegetation in- and out-of-current (**Figure 7.3**). There were 25 taxa (**Table 7.2**), a Total SASS score of 151 and an ASPT of 6.0 recorded in August 2022, with 23 taxa (**Table 7.3**), Total SASS score of 140 and ASPT of 6.1 recorded during May 2023. The Present Ecological Status was a **B/C** category (**Table 7.5**), being largely natural to moderately modified. The most impacted driver metric was that of water quality, followed by instream habitat and flow modification. Impacts include some nutrient enrichment at the site, as well as bed modification due to some algal growth. Taxa characterizing the site include Atyidae, Leptophlebiidae, Chlorocyphidae, Hydropsychidae, Philopotamida, Psephenidae, Dixidae and Simuliidae.



Upstream view



Downstream view

Figure 7.3 **Aquatic habitat for macroinvertebrates at 3_Olifantspruit**

Table 7.5 **Results of the MIRAI assessment for 3_Olifantspruit**

MIRAI		CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE	RANK	%WEIGHT
FLOW MODIFICATION	FM	83.2	0.32	26.7	2	90
HABITAT	H	83.0	0.32	26.6	2	90
WATER QUALITY	WQ	79.3	0.35	28.3	1	100
CONNECTIVITY & SEASONALITY	CS	90.0	0.00	0	4	0
INVERTEBRATE SCORE (%)				81.7		
INVERTEBRATE CATEGORY				**B/C**		

7.2.3.4 4_Mogalakwena1

4_Mogalakwena is in the Limpopo Plain 1.03 Ecoregion in the Lower Foothills. There were cobble runs with good quantities of sand, gravel and mud, and marginal vegetation in- and out-of-current present (**Figure 7.4**). There were 19 taxa (**Table 7.2**), a Total SASS score of 125 and an ASPT of 6.6 in August 2022, and 18 taxa (**Table 7.3**), Total SASS score 116 and ASPT of 6.4 during May 2023. The Present Ecological Status was a **C** Category (**Table 7.6**), with water quality the most impacted driver metric, followed by instream habitat. Impacts include nutrient enrichment from upstream settlements, towns, agriculture and livestock, sedimentation of instream stones and excessive algal growth. Taxa characterising the site included Atyidae, Heptageniidae, Coenagrionidae, Gomphidae, Hydropsychidae, Philopotamidae and Simuliidae.



Upstream view



Downstream view

Figure 7.4: Aquatic habitat for macroinvertebrates at 4_Mogalakwena1

Table 7.6: Results of the MIRAI assessment for 4_Mogalakwena1

MIRAI		CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE	RANK	%WEIGHT
FLOW MODIFICATION	FM	83.4	0.32	26.8	2	90
HABITAT	H	76.7	0.32	24.6	2	90
WATER QUALITY	WQ	73.8	0.35	26.3	1	100
CONNECTIVITY & SEASONALITY	CS	60.0	0.00	0		
INVERTEBRATE SCORE (%)				77.8		
INVERTEBRATE CATEGORY				**C**		

7.2.3.5 5_Mogalakwena2

5_Mogalakwena2 is situated downstream of Glen Alpine Dam and is in the Limpopo Plain 1.02 Ecoregion and Lower Foothills geomorphological zone. There was a good diversity of cobbles in- and out-of-current present, with a good quantity of GSM and marginal vegetation (**Figure 7.5**). There were 24 taxa (**Table 7.2**), a Total SASS score of 133 and ASPT of 5.5 in August 2022, and 18 taxa (**Table 7.3**), Total SASS score of 90 and ASPT of 5.0 in May 2023. The Present Ecologial Status was a **C** category (**Table 7.7**), indicating a moderately modified ecological condition. Water quality was the most impacted driver, with impacts from human settlements, agriculture, and livestock upstream. Instream habitat was also affected by higher-than-expected fine sediments and algal growth. Taxa characterising the site included Atyidae, Potamonautidae, Caenidae, Leptophlebiidae, Coenagrionidae, Hydropsychidae, Hydroptilidae, Simuliidae and Thiaridae.

	
Upstream view	Downstream view

Figure 7.5: Aquatic habitat for macroinvertebrates at 5_Mogalakwena2

Table 7.7: Results of the MIRAI assessment for 5_Mogalakwena2

MIRAI		CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE	RANK	%WEIGHT
FLOW MODIFICATION	FM	83.0	0.32	27.1	2	95
HABITAT	H	80.2	0.31	24.8	3	90
WATER QUALITY	WQ	64.7	0.34	22.3	1	100
CONNECTIVITY & SEASONALITY	CS	90.0	0.01	1.5	4	5
INVERTEBRATE SCORE (%)				75.9		
INVERTEBRATE CATEGORY				**C**		

7.2.3.6 6_Kolope

6_Kolope was in the Limpopo Plain 1.01 Ecoregion (**Figure 7.6**). There was no surface water present during both site visits, therefore no samples were collected and no MIRAI assessment was made.

	
Upstream view	Downstream view

Figure 7.6: Aquatic habitat for macroinvertebrates at 6_Kolope

7.2.3.7 7_Sand

7_Sand was in the Limpopo Plain 1.02 Ecoregion (**Figure 7.7**). There was no surface water present during both site visits, therefore no samples were collected and no MIRAI assessment was made.

	
Upstream view	Downstream view

Figure 7.7: Aquatic habitat for macroinvertebrates at 7_Sand

7.2.3.8 8_Nzhelele

8_Nzhelele is situated in the Limpopo Plain 1.01 Ecoregion, in the Lower Foothills geomorphological zone. There was a section of riffles and runs present, with a moderate quality of stones in- and out-of-current due to the presence of fine sediment and filamentous algae on the stones (**Figure 7.8**). There was a large amount of sand, gravel, and mud, as well as marginal vegetation present. There were 28 taxa (**Table 7.2**) and a Total SASS score of 158 and ASPT of 5.6 present during August 2022, and 25 taxa (**Table 7.3**), a Total SASS score of 162 and an ASPT of 6.5. The Present Ecological Status was a **C** Category (**Table 7.8**), being moderately modified. The most impacted driver metric was that of water quality, followed by flow modification. The Nzhelele Dam is situated upstream of the site and therefore impacts the natural flow in the system in a negative manner. Taxa characterising the site included Potamonautidae, Atyidae, Hydracarina, Leptophlebiidae, Oligoneuridae, Tricorythidae, Gomphidae, Philopotamidae, Elmidae, Tabanidae and Thiaridae.



Upstream view	Downstream view

Figure 7.8: Aquatic habitat for macroinvertebrates at 8_Nzhelele

Table 7.8: Results of the MIRAI assessment for 8_Nzhelele

MIRAI		CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE	RANK	%WEIGHT
FLOW MODIFICATION	FM	79.6	0.32	26.0	2	90
HABITAT	H	81.9	0.29	23.8	3	80
WATER QUALITY	WQ	76.7	0.36	27.8	1	100
CONNECTIVITY & SEASONALITY	CS	10.0	0.01	0.1	4	5
INVERTEBRATE SCORE (%)				77.9		
INVERTEBRATE CATEGORY				**C**		

7.2.3.9 9_Ṅwaneḍi

9_Ṅwaneḍi is situated in the Soutpansberg 2.02 Ecoregion in the Lower Foothills geomorphological zone. The site is characterized by a small riffle/run cobble section, which opens into a pool section, with good quantities of sand present (**Figure 7.9**). Very little marginal vegetation was available for macroinvertebrate colonization. There were 23 taxa present (**Table 7.2**) and a Total SASS score of 127 with a corresponding ASPT score of 5.5 during August 2022, and 21 taxa (**Table 7.3**), a Total SASS score of 122 and ASPT of 5.8 during May 2023. The Present Ecological Status was a **C** category (**Table 7.9**). Sedimentation and algal growth impact the site negatively, with the site utilized regularly by livestock for drinking. An upstream dam is also present, with water quality impacts due mainly to agricultural activities in the upper catchment. Taxa characterising the site included Caenidae, Leptophlebiidae, Chlorocyphidae, Gomphidae, Hydropsychidae, Philopotamidae, Leptoceridae and Athericidae.



Upstream view



Downstream view

Figure 7.9: Aquatic habitat for macroinvertebrates at 9_Ṅwaneḍi

Table 7.9: Results of the MIRAI assessment for 9_Ṅwaneḍi

MIRAI		CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE	RANK	%WEIGHT
FLOW MODIFICATION	FM	75.0	0.32	24.5	2	95
HABITAT	H	64.5	0.31	20.0	3	90
WATER QUALITY	WQ	68.3	0.34	23.5	1	100
CONNECTIVITY & SEASONALITY	CS	48.9	0.01	0.8	4	5
INVERTEBRATE SCORE (%)				68.9		
INVERTEBRATE CATEGORY				**C**		

7.2.3.10 10_Latonyanda

10_ Latonyanda is situated in a forestry area, in the Lowveld 3.01 Ecoregion, within the Upper Foothills geomorphological zone. The site comprised cobble-riffle and run sections with marginal vegetation including graminoids and broadleaved vegetation (**Figure 7.10**). Some GSM was present at the site. The site was not sampled in August 2022 because flows were too high to get in the river. There were 27 taxa (**Table 7.3**) and a Total SASS score of 183 with ASPT score of 6.8 during May 2023. The present ecological condition was a **B/C** category (**Table 7.10**), which corresponds to a moderately modified ecological condition. The most impacted driver metric was that of instream habitat, due mostly to increased instream sedimentation, followed by the water quality metric. Taxa characterising the site included Perlidae, Heptageniidae, Leptophlebiidae, Tricorythidae, Gomphidae, Hydropsychidae, Philopotamidae, Leptoceridae, Psephenidae, Athericidae and Simuliidae.



Upstream view



Downstream view

Figure 7.10: Aquatic habitat for macroinvertebrates at 10_Latonyanda

Table 7.10: Results of the MIRAI assessment for 10_Latonyanda

MIRAI		CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE	RANK	%WEIGHT
FLOW MODIFICATION	FM	82.0	0.33	27.3	1	100
HABITAT	H	77.6	0.33	25.8	1	100
WATER QUALITY	WQ	78.2	0.33	26.0	1	100
CONNECTIVITY & SEASONALITY	CS	100.0	0.00	0	2	0
INVERTEBRATE SCORE (%)				79.2		
INVERTEBRATE CATEGORY				**B/C**		

7.2.3.11 11_Mutshindudi

11_Mutshindudi is situated in the Soutpansberg 2.04 Ecoregion in the Lower Foothills geomorphological zone. There was a good section of cobbles and boulders in- and out-of-current, as well as marginal vegetation and GSM present (**Figure 7.11**). There was a cascade at the upper end that flows into a large pool. During August 2022 a total number of 28 taxa were identified (**Table 7.2**), with a Total SASS score of 169 and ASPT of 6.0 obtained. Thirteen taxa (**Table 7.3**), a Total SASS and ASPT score of 94 and 7.2 respectively, were obtained during May 2023. The Present Ecological Status was a C category (**Table 7.11**), being moderately modified. The most impacted driver metric was that of water quality, followed by instream habitat. Impacts are due to upstream settlements and livestock utilization of the river, as well as to increased sedimentation and algal growth on the available benthic habitat. Taxa characterizing the site include Perlidae, Heptageniidae, Leptophlebiidae, Gomphidae, Hydropsychidae, Leptoceridae, Dytiscidae, Athericidae, Simuliidae and Thiaridae.



Upstream view | Downstream view

Figure 7.11: Aquatic habitat for macroinvertebrates at 11_Mutshindudi

Table 7.11: Results of the MIRAI assessment for 11_Mutshindudi

MIRAI		CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE	RANK	%WEIGHT
FLOW MODIFICATION	FM	78.2	0.31	24.7	2	90
HABITAT	H	77.9	0.31	24.5	2	90
WATER QUALITY	WQ	74.6	0.35	26.1	1	100
CONNECTIVITY & SEASONALITY	CS	80.0	0.018	1.4	3	5
INVERTEBRATE SCORE (%)				76.8		
INVERTEBRATE CATEGORY				**C**		

7.2.3.12 12_Luvuvhu

12_Luvuvhu is situated in the Lowveld 3.03 Ecoregion in the Lower Foothills geomorphological zone. The site comprises extensive cobble/boulder run sections, with a good quality and quantity of cobbles present (**Figure 7.12**). There were 28 taxa (**Table 7.2**) and Total SASS and ASPT scores of 190 and 6.8 respectively in August 2022, and 28 taxa (**Table 7.3**) and Total SASS and ASPT scores of 185 and 6.6 respectively in May 2023. The Present Ecological Status was a B/C category (**Table 7.12**), being largely natural to moderately modified. The most impacted driver metric was that of water quality, followed by instream habitat modification. Impacts include nutrient enrichment from human settlements and livestock utilization of the river, as well as increased sedimentation and algal growth on the benthic habitat. Taxa characterising the site included Atyidae, Perlidae, Heptageniidae, Leptophlebiidae, Coenagrionidae, Gomphidae, Crambidae, Hydropsychidae, Leptoceridae, Elmidae, Psephenidae, Athericidae, Simuliidae and Thiaridae.



Upstream view



Downstream view

Figure 7.12: Aquatic habitat for macroinvertebrates at 12_Luvuvhu

Table 7.12: Results of the MIRAI assessment for 12_Luvuvhu

MIRAI		CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE	RANK	%WEIGHT
FLOW MODIFICATION	FM	82.1	0.33	27.8	1	100
HABITAT	H	79.5	0.30	24.2	2	90
WATER QUALITY	WQ	76.0	0.33	25.7	1	100
CONNECTIVITY & SEASONALITY	CS	83.3	0.01	1.4	3	5
INVERTEBRATE SCORE (%)				79.2		
INVERTEBRATE CATEGORY				**B/C**		

7.2.3.13 13_Mutale1

13_Mutale1 is in the Soutpansberg 2.04 Ecoregion in the Lower Foothills geomorphological zone. There were bedrock/boulder runs and rapids, no GSM and some marginal vegetation present (**Figure 7.13**). There were 23 taxa (**Table 7.2**) and Total SASS and ASPT scores of 137 and 6.0 respectively in August 2022, and 19 taxa (**Table 7.3**) and Total SASS and ASPT scores of 144 and 7.6 respectively. The Present Ecological Status was a C category (**Table 7.13**), being moderately modified. Water quality was the most impacted driver, with impacts from subsistence farming and livestock watering. Instream habitat was the second most impacted metric, with impacts including sedimentation of instream habitat and algal growth. Taxa characterising the site included Perlidae, Heptageniidae, Oligoneuridae, Libelullidae, Hydropsychidae, Philopotamidae, Leptoceridae, Psephenidae and Simuliidae.



Upstream view



Downstream view

Figure 7.13: Aquatic habitat for macroinvertebrates at 13_Mutale1

Table 7.13: Results of the MIRAI assessment for 13_Mutale1

MIRAI		CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE	RANK	%WEIGHT
FLOW MODIFICATION	FM	73.1	0.32	23.4	2	90
HABITAT	H	64.1	0.32	20.5	2	90
WATER QUALITY	WQ	63.3	0.35	22.6	1	100
CONNECTIVITY & SEASONALITY	CS	88.9	0.00	0	3	0
INVERTEBRATE SCORE (%)				66.6		
INVERTEBRATE CATEGORY				**C**		

7.2.3.14 14_Mutale2

14_Mutale2 is in the Soutpansberg 2.02 Ecoregion in the Upper Foothills geomorphological zone. There were cobble/boulder riffles and runs, with good sand, some gravel and mud and marginal vegetation present (**Figure 7.14**). There were 28 taxa (**Table 7.2**) and Total SASS and ASPT scores of 180 and

6.4 respectively in August 2022, and 244 taxa (**Table 7.3**) and Total SASS and ASPT scores of 162 and 6.8 respectively in May 2023. The Present Ecological Status was a C category (**Table 7.14**) with water quality and sedimentation of instream habitats being the main drivers of condition, affected by upstream settlements, lodges, subsistence farming and algal growth. Taxa characterising the site included Paleomonid prawns, Perlidae, Heptageniidae, Oligoneuridae, Tricorythidae, Coenagrionidae, Gomphidae, Hydropsychidae, Philopotamidae, Leptceridae, Athericidae, Simuliidae and Thiaridae.



Upstream view



Downstream view

Figure 7.14: Aquatic habitat for macroinvertebrates at 14_Mutale2

Table 7.14: Results of the MIRAI assessment for 14_Mutale2

MIRAI		CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE	RANK	%WEIGHT
FLOW MODIFICATION	FM	81.2	0.30	24.7	2	90
HABITAT	H	80.5	0.33	27.3	1	100
WATER QUALITY	WQ	68.7	0.33	23.2	1	100
CONNECTIVITY & SEASONALITY	CS	95.0	0.01	1.6	3	5
INVERTEBRATE SCORE (%)				76.9		
INVERTEBRATE CATEGORY				**C**		

7.3 Aquatic macroinvertebrate indicators

A list of macroinvertebrate indicators and reasons for their selection is given in **Table 7.15**. Some habitat preferences are given in **Table 7.16**

Table 7.15: Macroinvertebrate indicators and reasons for their selection

Indicator	Reasons for selection	1_Lephalala	2_Rietfontein *	3_Olifantspruit	4_Mogalakwena 1	5_Mogalakwena 2	8_Nzhelele	9_Ṅwaneḍi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale 1	14_Mutale 2	1_Lephalala	2_Rietfontein *
Atyidae	Freshwater shrimps are vegetation dwellers that prefer standing water, i.e. <0.1 m/s, with a moderate sensitivity to changes in water quality.														
Perlidae	Perlidae show preference for the cobble biotope and prefer fast flowing water, i.e., 03.-0.6 m/s. They are highly sensitive to changes in water quality.														
Heptageniidae	The Heptageniidae show preference for the cobble biotope, prefer velocities from 0.3 – 0.6 m/s and are highly sensitive to changes in water quality.														
Coenagrionidae	These taxa occur in the marginal vegetation and show a preference for standing waters, i.e., < 0.1 m/s. They have a low sensitivity to changes in water quality.														
Gomphidae	Gomphidae occur in the GSM (Gravel, Sand & Mud) biotope and show a preference for velocities < 0.1 m/s. They have a low sensitivity to changes in water quality.														
Hydropsychidae	These taxa show preference for very fast velocities, i.e., > 0.6 m/s, prefer the cobble biotope and have a range of sensitivities to water quality, from low to highly sensitive taxa.														

Indicator	Reasons for selection	1_Lephalala	2_Rietfontein *	3_Olifantspruit	4_Mogalakwena 1	5_Mogalakwena 2	8_Nzhelele	9_Ṅwaneḍi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale 1	14_Mutale 2	1_Lephalala	2_Rietfontein *
	Some species can withstand slower velocities.														
Simuliidae	Simuliidae occur in all the different biotopes but show a stronger preference for the cobble and bedrock/boulder biotopes. They prefer velocities > 0.6 m/s.														
Caenidae	Caenidae show a strong preference for the GSM biotope and prefer slower velocities to standing water (<0.1 m/s). They have a low sensitivity to changes in water quality.														

Table 7.16: Velocity, habitat, and water quality preferences of the indicators (Thirion 2016)

Taxon	Velocity Preference	Habitat	Water quality	Sensitivity rating	FFG
Atyidae (Freshwater Shrimps)	Standing (<0.1m/s)	Vegetation	Moderate	8	CG
Coenagrionidae (Sprites & Blues)	Standing (<0.1m/s)	Vegetation	Low	4	P
Perlidae (Stoneflies)	Moderately fast (0.3 - 0.6m/s)	Cobbles	Highly Sensitive	12	P
Hydropsychidae (Caddisflies)	Very fast (>0.6m/s)	Cobbles	Range of sensitivities	4 - 12	F
Heptageniidae (Flatheaded mayfly)	Moderately fast (0.3 - 0.6m/s)	Cobbles	Highly Sensitive	13	CG
Gomphidae (Clubtails)	Standing (<0.1m/s)	GSM	Low	6	P
Simuliidae (Blackflies)	Very fast (>0.6m/s)	Cobbles, boulders	Low	5	F
Caenidae (Squaregills/Cainflies)	Standing (<0.1m/s)	GSM	Low	6	CG, SG

FFG = Functional Feeding Group, P = predatory, CG = collector/gatherer, F = filterer, SG = scraper/grazer, S = shredder, Veg = vegetation, GSM = gravel/sand/mud

7.3.1 Atyidae (shrimp)

Atyidae (Freshwater shrimps, **Figure 7.15**) prefer standing water (<0.1m/s), the vegetation biotope and have a moderate water quality preference (Thirion 2016). They can be scavengers, filter feeders or

collector-gatherers feeding on animal and plant detritus as well as algae and use their brush-like chelae to collect food particles off rock and plant surfaces. More than 650 shrimp species (Decapoda: Caridea) occur in freshwater habitats (De Grave *et al.* 2008) and play an important role in stream food webs and ecosystem function (Yatsuya *et al.* 2013). Herbivorous and detritivorous shrimp (Atyidae) in tropical streams influence primary production, leaf-litter breakdown, and the benthic community structure (Yatsuya *et al.* 2013). Moreover, these primary consumers are important food sources for predators (Covich and McDowell 1996).

The reason for selecting the linked indicator and its relationship with Atyidae is summarised in **Table 7.17.**



Figure 7.15: Atyidae (DWAF 2002)

Table 7.17: Linked indicator and its relationship with Atyidae

Linked indicator	Reasons	Relationship
Marginal zone vegetation	Atyidae live and feed in marginal vegetation (Yam and Dudgeon 2005).	More marginal vegetation = more Atyidae.

7.3.2 Perlidae (stoneflies)

Perlidae (Stoneflies) are a species rich stonefly family **Figure 7.16**), with almost 1000 species worldwide (Macroinvertebrates 2023). Stonefly larvae (also called nymphs or naiads) are aquatic, flattened, with 6 sprawling legs and with a segmented abdomen bearing 2 long antenna-like “tails” (cerci). The antennae on the head are long. Gills are tuftlike and usually positioned at the bases of the legs, on the underside of the body. Larvae are small- to medium- sized, with distinctive dorsal patterns. Perlidae larvae cling to substrate in riffles and are very sensitive to changes in water quality and show preference for moderately fast flowing water (0.3 – 0.6m/s) and for the cobble biotope (Thirion 2016). These taxa are not active flyers and tend to remain close to the river (www.discoverlife.org) Neoperla sp. lay approximately between 50 - 300 eggs per egg mass (Vaught 1972). As predators, Perlidae nymphs prey aggressively on small invertebrates but rely on a substrate free of thick filamentous algae as favourable habitat. Plecoptera are particularly vulnerable to increases in turbidity which has been shown to negatively affect species richness and abundance (Lee *et al.* 2022).



Figure 7.16: Neoperla spp. (https://www.macroinvertebrates.org/taxa-info/plecoptera-larva/perlidae/neoperla/dorsal)

The reason for selecting linked indicators and their relationship with Perlidae are summarised in **Table 7.18**.

Table 7.18: Linked indicators and their relationship with Perlidae

Linked indicator	Reasons	Relationship
Dry average velocity Wet average velocity Wet maximum velocity	Perlidae need fast, shallow turbulent flow that is well oxygenated (Bouchard 2004). At very high velocities (>0.9 m/s), Perlidae are scoured and washed downstream (Long et al. 2011).	Low velocities = fewer Perlidae, high velocities = more Perlidae.
Embeddedness	Perlidae like clean stones because interstitial spaces provide refuge from disturbance and habitat to hunt and lay eggs (Lee et al. 2022).	Greater embeddedness = fewer Perlidae
Riffles	Perlidae are sensitive to oxygen concentrations and so are confined to well-oxygenated turbulent flows in riffles and cascades.	Fewer riffles = fewer Perlidae.
Electrical conductivity	Perlidae require unpolluted and swift flowing water with high oxygen content (Hilsenhoff 2001) and have a high requirement for unmodified water quality (Thirion 2016).	Higher Eletrcical Conductivity = fewer Perlidae.
Filamentous algae	Perlidae need stones free from algae (Lee et al. 2022).	More filamentous algae = fewer Perlidae.

7.3.3 Heptageniidae (flathead mayflies)

Heptageniidae (Flatheaded mayflies **Figure 7.17**) show preference for moderately fast flowing water (0.3 – .6m/s), the cobble biotope and are highly sensitive to changes in water quality (Thirion 2016). They are usually found in lotic habitats, but some occur in lentic erosional habitats, often among rocks. They are most common in waters that are cool, clean, and shallow, such as shallow streams and at the edges of lakes near the shore (Science Direct 2023a). They typically feed by scraping algae and periphyton from rocks and other substrates at the bottom of streams (Macroinvertebrates 2023). Heptageniidae are multivoltine, asynchronous, have overlapping generations and continuous emergence, hence recruitment occurs throughout the year (Sivaruban *et al.* 2010).



Figure 7.17: Heptageniidae (DWAF 2002)

The reason for selecting linked indicators and their relationship with Heptageniidae are summarised in **Table 7.19**.

Table 7.19: Linked indicators and their relationship with Heptageniidae

Linked indicator	Reasons	Relationship
Dry minimum velocity	Heptageniidae prefer moderate flow (0.3-0.6m/s, Thirion 2016).	Low velocities = fewer heptageniids, high velocities = more Heptageniidae.
Wet minimum velocity		
Wet maximum velocity		
Embeddedness	Heptageniidae like clean cobbles (Thirion 2007; Mathews 1968) because sediments abrade and clog their gill filters (USEPA, 2003).	Higher embeddedness = fewer Heptageniidae.
Riffles	Heptageniidae like moderate flowing water on clean cobbles.	More riffles = more Heptageniidae.
Electrical conductivity	Heptageniidae are sensitive to increased electrical conductivity (Horrigan et al. 2005), and are sensitive to poor water quality (Thirion 2016).	Higher Ecological Category = fewer Heptageniidae.
Filamentous algae	Heptageniidae like clean cobbles (Thirion 2007; Mathews 1968) with no algae.	More filamentous algae = fewer Heptageniidae.

7.3.4 Coenagrionidae (Sprites and Blues)

Coenagriondiae (Sprites and Blues, **Figure 7.18**) are a damselfly family, of which the nymphs are climbers and stalking predators among plants and roots (Macroinvertebrates 2023). Most Southern African Odonata species prefer the well-lit, weedy margins of pools, streams and rivers (Samways *et al.,* 1996). Coenagrionidae show preference for standing water (<0.1m/s), for the vegetation biotope and have a low water quality preference (Thirion 2016). Most Coenagrionidae are univoltine, a few are bivoltine, and others are multivoltine (Phiri *et al*. 2012). Adult flying periods range from spring to autumn, during which females deposit the eggs in vegetation. Some species produce eggs that can over-winter and these species usually deposit eggs in autumn and the larvae emerge in spring (Centre for Freshwater Biology 2023).



Figure 7.18: Coenagriondiae (DWAF 2002)

The reason for selecting the linked indicator and its relationship with Coenagriondiae is summarised in **Table 7.20**.

Table 7.20: Linked indicators and their relationship with coenagrionids

Linked indicator	Reasons	Relationship
Marginal zone vegetation	Coenagriondiae prefer marginal vegetation (Thirion 2016).	More marginal vegetation = more Coenagriondiae.

7.3.5 Gomphidae (Clubtails)

Gomphidae (Clubtails, **Figure 7.19**) are a family of Odonata (Dragonflies) and are widespread throughout the world, with *Gomphus* the largest genus (Centre for Freshwater Biology 2023). Gomphids show preference for standing water (<0.1m/s), for the GSM biotope and have a low water quality preference (Thirion 2016). Gomphidae show preference for sand habitat with particle size 0.6 - 1mm (Huggins & DuBois 1982). Gomphidae are year-round residents that are non-dispersing (UNDP-GEF 2013). Literature shows them to be semivoltine - i.e., generation time is greater than one year (Burcher & Smock 2002). Larvae can be found burrowing in the substrate made of sand or silt, in the riffles of streams, with some species found in lentic ponds and lakes with littoral areas (Thorp and Covich 2010). Many species have over-wintering eggs and may require 2-4 years to complete their life cycle. Water temperature and availability of food are key factors in the duration of the life cycle (Thorp and Covich 2010). Emergence of larvae occurs in early spring and can last up to two months depending on temperatures. Larvae are ambush predators that hide in decaying debris on the bottom of lakes, ponds, and streams where they engulf their prey.



Figure 7.19: Gomphidae (DWAF 2002)

The reason for selecting linked indicators and their relationship with Gomphidae are summarised in **Table 7.21**.

Table 7.21: Linked indicators and their relationship with Gomphidae

Linked indicator	Reasons	Relationship
Inundated sandy habitat	Gomphidae prefer sand with a particle size of 0.6 - 1mm (Huggins & DuBois 1982).	More sand = more gomphids.
Filamentous algae	Gomphidae like clean sand so an increase in algae will have a negative impact on their preferred habitat.	More algae = less gomphids.

7.3.6 Hydropsychidae (Seine-net weaver caddisflies)

Hydropsychidae (Seine-net Weaver Caddisflies, **Figure 7.20**) consist of net-spinning caddisflies, are common worldwide in streams, with the larval stage spent entirely in freshwater (Wikipedia 2023). Larvae are abundant in all kinds of freshwater ecosystems from spring sources, mountain stream large rivers to splash zones of waterfalls, among others (WRC 2003b). They are identified by the numerous, branched filamentous gills that occur ventrally on their abdomen (Science Direct 2023). Hydropsychidae show preference for very fast flowing water (>0.6m/s), for the cobble biotope and possess a range of sensitivities to poor water quality (Thirion 2016). Larvae are omnivorous and a capture net is used to filter food particles from the water column, including algae, small invertebrates, and organic particles (Centre for Freshwater Ecosystems 2023). Drift is the main dispersal mechanism for egg masses released directly into the water, with Hydropsychidae that make use of active drift mechanisms generally over short distances for dispersal. Hydropsychidae are more prone to drift during floods (Science Direct 2023).



Figure 7.20: Hydropsychidae (DWAF 2002)

The reasons for selecting linked indicators and their relationship with Hydropsychidae are summarised in **Table 7.22**.

Table 7.22: Linked indicators and their relationship with Hydropsychidae.

Linked indicator	Reasons	Relationship
Dry minimum velocity	Hydropsychidae prefer very fast flowing water (Thirion 2016).	Lower velocities = fewer Hydropsychidae.
Wet minimum velocity	Less discharge will have a negative impact on Hydropsychidae which are flow sensitive (Thirion 2016). An increase in discharge will result in an increase in average and maximum velocities which will affect the Hydropsychidae positively with a resultant increase in abundance. Some species can withstand slower velocities; hence less discharge will not have as severe a negative impact on Hydropsychidae.	Less discharge = generally less Hydropsychidae
Wet maximum velocity		
Embeddedness	Hydropsychidae prefer clean cobbles free from fine sediments (Thirion 2007) that clog their filter feeding appendages (USEPA 2003).	More embeddedness = fewer Hydropsychidae.
Riffles	Hydropsychidae like fast flowing water over clean cobbles.	More riffles = more Hydropsychidae.
Filamentous algae	Hydropsychidae like clean cobbles with no filamentous algae.	More filamentous algae = fewer Hydropsychidae.

7.3.7 Simuliidae (Blackflies)

Simuliidae (Blackflies, **Figure 7.21**) show preference for very fast flowing water (>0.6m/s), the cobble biotope and have a low sensitivity to changes in water quality (Thirion, 2016). Simuliidae are filter feeders and cannot survive without flowing water (about 0.5 m/s) because they feed on particles moving past in the water column (McNair et al. 1997). They favour immobile substrates and fix themselves to the substrate and take advantage of fast, turbulent flows for capturing suspended particles in the water column (Vazques et al. 2020). They filter food particles from the current with specialised fans (Griffiths *et al.* 2015). Simuliidae therefore tend to dominate large boulders and bedrock and are also found

attached to vegetation. The larval and pupal stages are best adapted to life in fast-flowing water and therefore an absence of suitable flowing water, is a limiting factor in their distribution (WRC, 2003c). Many Simuliidae are of economic, veterinary, and medical importance because they are vectors of disease, for example river blindness (Griffiths *et al.* 2015, WRC 2003c). The larvae of most species go through seven instars before pupating. Pupae are enclosed in a silken cocoon attached to various substrates (WRC 2003c). Because they are specialists of rapids and because of their abundance, they are considered an important component of the aquatic food chain in swift-flowing water (WRC 2003c).



Figure 7.21: Simuliidae (DWAF 2002)

The reason for selecting linked indicators and their relationship with Simuliidae are summarised in **Table 7.23**.

Table 7.23: Linked indicators and their relationship with Simuliidae

Linked indicator	Reasons	Relationship
Dry average velocity	Simuliidae inhabit water that flows faster than 0.5 m/s to filter feed (McNair et al. 1997).	Very low velocities = fewer Simuliidae and higher velocities = more Simuliidae.
Wet minimum velocity		
Wet maximum velocity		
Riffles	Simuliidae attach to stones in fast flowing water.	More riffles = more Simuliidae.
Filamentous algae	Filamentous algae grow over cobbles and reduce the abundance of clean surfaces the Simuliidae prefer (Dean and Selckmann 2015).	More filamentous algae = fewer Simuliidae.
Marginal zone plants	Simuliidae attach to marginal zone plants.	More marginal zone plants = more Simuliidae.

7.3.8 Caenidae (Squaregill mayflies)

Caenidae or squaregill mayflies (**Figure 7.22**), are found throughout the world in lotic, depositional environments, in slow-flowing areas of streams, rivers and lakes with silty substrate, to which their gills are specifically adapted for such environments (iNaturalist 2023). They show preference for standing water (<0.1m/s), for the GSM biotope and have a low water quality preference (Thirion, 2016). Nymphs feed on fine particulate detritus and periphyton (WRC 2003a). The operculate gills (gill covers)

are thought to protect the other delicate posterior gills from becoming clogged by fine sediment (Dean and Suter, 1996). They are sprawling nymphs and poor swimmers that mostly crawl along the riverbed. The body is covered in a layer of fine hairs. Caenidae typically have one or two generations per year, with adults emerging in spring and summer (Macroinvertebrates 2023).



Figure 7.22: Caenidae (Malzacher & Staniczek 2007)

The reasons for selecting linked indicators and their relationship with Caenidae are summarised in **Table 7.24**.

Table 7.24: Linked indicators and their relationship with Caenidae

Linked indicator	Reasons	Relationship
Flow days >= 5cm	Caenidae inhabit shallow slow flowing water (Thirion 2016).	More continuous flow days = more Caenidae.
Inundated sandy habitat	Caenidae prefer silt and loose sediment (Corbin and Goonan 2010).	More inundated sandy habitat = more Caenidae.
Filamentous algae	Filamentous algae reduce the abundance of clean sands favoured by Caenidae (Dean and Selckmann 2015).	More filamentous algae = fewer Caenidae.

7.4 Status and trends

7.4.1 Atyidae

Relevant at EWR sites 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu.

Increased human settlements have taken place since 1960 onwards, which resulted in increased sedimentation and pollutants entering the catchment, as well as a decrease in the amount of marginal vegetation present due to increased livestock present at sites 11_Mutshindudi and 12_Luvuvhu. Two large, instream dams, the Albasini Dam, opened in 1952 and the Nandoni Dam opened in 2005, would have had large impacts on the natural flow in the Luvuvhu River, downstream of the dams, as well as retention of sediment in these impoundments. At site 10_Latonyanda, afforestation has occurred since the 1960s, which results in increased sedimentation of benthic habitat at the site.

The three main anthropogenic drivers of indicator status are:

- Sedimentation due to increased erosion and removal of marginal vegetation due to livestock activity at the sites, as well as to afforestation at the Latonyanda site.
- Changes to the natural flow regimes, resulting in increased or decreased discharge which will change the water level and thus the amount of inundated marginal vegetation available for Atyidae.
- Removal of marginal vegetation due to the presence of livestock.

Assuming the 2023 quantity (in terms of abundance and diversity of species) of Atyidae is 100%, the estimated quantity in:

c. 1900 was:

- 110% in 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu because very few anthropogenic impacts would have existed at this time and Atyidae would have proliferated under natural to near natural conditions present in these systems, due to the presence of marginal vegetation along the banks of the rivers.

c. 1960 was:

- 105% in 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu due to some pressure present because of increased livestock presence at the sites, as well as potential removal of marginal vegetation by anthropogenic activity.

c. 2000 was:

- 102% in 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu because impacts present are those from increased livestock activity and increased erosion and sedimentation.

7.4.2 Perlidae and Heptageniidae

Relevant at EWR sites 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_ Mutale1, 14_Mutale2.

At site 10_Latonyanda, afforestation has occurred which results in increased sedimentation of benthic habitat in the catchment. Increased human settlements have taken place since 1960 onwards, which resulted in increased sedimentation and pollutants entering the catchment, as well as a decrease in the amount of marginal vegetation present due to increased livestock present at sites 11_Mutshindudi and 12_Luvuvhu. Two large, instream dams, the Albasini Dam, opened in 1952 and the Nanḓoni Dam opened in 2005, would have had large impacts on the natural flow in the Luvuvhu River, downstream of the dams, as well as retention of sediment in these impoundments. There has been increased anthropogenic activity in the Mutale River catchment since 1960, including the presence of livestock as well as increased nutrients due to an increase in the number of human settlements in the catchment.

The three main anthropogenic drivers of indicator status are:

- Sedimentation due to increased erosion and removal of marginal vegetation due to livestock activity at the sites.
- Changes in natural flow patterns due to the presence of large, instream dams.
- Water quality impacts due to pollutants entering the system.
- Decreased number of riffles and benthic habitat due to inundation by instream dams, will impact the indicators negatively.

Assuming the 2023 quantity (in terms of abundance and diversity of species) of Perlidae and Heptageniidae is 100%, the estimated quantity in:

c. 1900 was:

- 130% at sites 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1, 14_Mutale2 because very few anthropogenic impacts would have existed at this time and Perlidae and Heptageniidae would have proliferated under natural to near natural conditions present in these systems.

c. 1960 was:

- 110% at sites 10_Latonyanda ,11_Mutshindudi, 13_Mutale1, 14_Mutale2 due to increased water quality impacts from anthropogenic activity in the catchments, increased erosion due to grazing of livestock and removal of riparian vegetation.
- 108% at 12_Luvuvhu site due to the presence of the Albasini Dam, constructed in 1952, which had a negative impact on the presence of these indicator taxa.

c. 2000 was:

- 105% at 10_Latonyanda, 11_Mutshindudi, 13_Mutale1, 14_Mutale2 due to increased nutrients entering the system and therefore increased algal growth which has a negative impact on the benthic habitat present, as well as increased sedimentation at the sites.
- 102% at 12_Luvuvhu due to the presence of the Nanḍoni Dam coming online in 2005, which had a negative impact on the presence of these indicator taxa.

7.4.3 Coenagrionidae

Relevant at EWR sites 1_Lephalala, 2_Rietfontein, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 7_Sand, 8_Nzhelele, 13_Mutale1, 14_Mutale2.

Nature reserves and game farming is the main land use in the upper Lephalala catchment and has increased since 1960 onwards, with some agriculture in the upper extremes of the catchment. Numerous weirs and farm dams exist, impacting the movement of aquatic fauna present in the upper Lephalala catchment, the majority of these would have been constructed post 1960.

In the Rietfontein catchment, some agriculture and game farming were the dominant land use since the 1960s onwards, having shown a slight impact on the instream integrity. Most of the systems in the area are spring-fed groundwater systems. Natural areas dominate the upper Olifantspruit, with minimal agriculture occurring since 1960 onwards, having minimal impact on the instream integrity.

Urbanization, agriculture, and mining activities in the upper Mogalakwena River catchment has taken place since 1960 onwards, which resulted in increased sedimentation and pollutants entering the catchment. Urbanization and agriculture in the upper Sand River catchment has taken place since 1960 onwards, which resulted in increased sedimentation and pollutants entering the Sand River catchment. The Kolope River is within the Mapungubwe Reserve and will have experienced an increased pressure due to the grazing of game in the area. The presence of an upstream weir and dam which was built presumably after 2000, has a negative impact on the flow within the Kolope, downstream of the weir.

There has been increased anthropogenic activity in the Mutale and Nzhelele River catchments since 1960, including the presence of livestock as well as increased nutrients due to an increase in the number of human settlements in the catchment. Instream dams also contribute to changes in the natural flow regimes of these rivers. The Nzhelele Dam was established in 1948 for irrigation purposes, which impacts the natural flow regime of the Nzhelele River, as well as the movement of biota and the transport of sediment in the system.

The three main anthropogenic drivers of indicator status are:

- Water quality impacts and the presence of filamentous algae due to nutrient enrichment.
- Changes in the natural flow regimes, with increased or decreased discharge which will change the water level and thus the amount of inundated marginal vegetation available for Coenagrionidae.
- Removal of marginal vegetation due to the presence of livestock.

Assuming the 2023 quantity (in terms of abundance and diversity of species) of Coenagrionidae is 100%, the estimated quantity in:

c. 1900 was:

- 120% in 1_Lephalala, 2_Rietfontein, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 13_Mutale1, 14_Mutale because very few anthropogenic impacts would have existed at this time and Coenagrionidae would have proliferated under natural to near natural conditions present in these systems, due to the presence of marginal vegetation along the banks of the rivers.
- 115% 6_Kolope, 7_Sand due to naturally less vegetation occurring at these two sites.

c. 1960 was:

- 110% in 1_Lephalala, 2_Rietfontein, 3_Olifantspruit, 8_Nzhelele, 13_Mutale1, 14_Mutale2 due to some pressure present because of increased livestock presence at the sites, as well as potential removal of marginal vegetation by anthropogenic activity.
- 105% at 6_Kolope, 7_Sand due potential livestock pressure on marginal vegetation present.

c. 2000 was:

- 102% in 1_Lephalala, 2_Rietfontein, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 13_Mutale1, 14_Mutale, because impacts present are those from increased livestock and game pressures on the marginal vegetation present.

7.4.4 Gomphidae

Relevant at EWR sites 1_Lephalala, 2_Rietfontein, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 7_Sand, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 14_Mutale2.

Nature reserves and game farming is the main land use in the upper Lephalala catchment and has increased since 1960 onwards, with some agriculture in the upper extremes of the catchment. Numerous weirs and farm dams exist, impacting the movement of aquatic fauna present in the upper Lephalala catchment, the majority of these would have been constructed post 1960.

In the Rietfontein catchment, some agriculture and game farming were the dominant land use since the 1960s onwards, having shown a slight impact on the instream integrity. Most of the systems in the area are spring-fed groundwater systems. Natural areas dominate the upper Olifantspruit, with minimal agriculture occurring since 1960 onwards, having minimal impact on the instream integrity.

Urbanization, agriculture, and mining activities in the upper Mogalakwena River catchment has taken place since 1960 onwards, which resulted in increased sedimentation and pollutants entering the catchment. Urbanization and agriculture in the upper Sand River catchment has taken place since 1960 onwards, which resulted in increased sedimentation and pollutants entering the Sand River catchment. The Kolope River is within the Mapungubwe Reserve and will have experienced an increased pressure

due to the grazing of game in the area. The presence of an upstream weir and dam which was built presumably after 2000, has a negative impact on the flow within the Kolope, downstream of the weir.

There has been increased anthropogenic activity in the Mutale and Nzhelele River catchments since 1960, including the presence of livestock as well as increased nutrients due to an increase in the number of human settlements in the catchment. Instream dams also contribute to changes in the natural flow regimes of these rivers. The Nzhelele Dam was established in 1948 for irrigation purposes, which will impact the natural flow regime of the Nzhelele River, as well as the movement of biota and the transport of sediment in the system. In the Ṅwaneḍi catchment, increased agriculture since the 1960s, with the establishment of the Ṅwaneḍi Dam in 1964 for irrigation purposes, has increased runoff and sedimentation in the system and thus decreased the integrity of the benthic habitat for aquatic biota.

Increased human settlements have taken place since 1960 onwards, which resulted in increased sedimentation and pollutants entering the catchment, as well as a decrease in the amount of marginal vegetation present due to increased livestock present at sites 11_Mutshindudi and 12_Luvuvhu. Two large, instream dams, the Albasini Dam, opened in 1952 and the Nanḍoni Dam opened in 2005, would have had large impacts on the natural flow in the Luvuvhu River, downstream of the dams, as well as retention of sediment in these impoundments. At site 10_Latonyanda, afforestation has occurred which results in increased sedimentation of benthic habitat in the catchment.

The three main anthropogenic drivers of indicator status are:

- Sedimentation due to increased erosion and removal of marginal vegetation due to livestock activity at the sites, as well as to afforestation in the Latonyanda Catchment.
- Changes in flow patterns due to the presence of large, instream dams.
- Water quality impacts due to nutrients entering the system and therefore potential increased filamentous algae present.

Assuming the 2023 quantity (in terms of abundance and diversity of species) of Gomphidae is 100%, the estimated quantity in:

c. 1900 was:

- 110% at sites 1_Lephalala, 2_Rietfontein, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 7_Sand, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 14_Mutale2 because very few anthropogenic impacts would have existed at this time and Gomphidae would have proliferated under natural to near natural conditions present in these systems.

c. 1960 was:

- 108% at sites 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 9_Ṅwaneḍi, 11_Mutshindudi, 12_Luvuvhu, 14_Mutale2 due to increased sedimentation from anthropogenic activity in the catchments, increased erosion due to grazing of livestock and removal of riparian vegetation.
- 107% at 10_Latonyanda due to increased sedimentation from afforestation at the site.

c. 2000 was:

- 105% at 1_Lephalala, 2_Rietfontein, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 7_Sand, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 14_Mutale2 due to increased nutrients entering the system and therefore increased algal growth which has a negative impact on the benthic habitat present, as well as an increase in sediment entering the systems.

7.4.5 Hydropsychidae

Relevant at EWR sites 4_Mogalakwena1, 8_Nzhelele, 9_Ṅwaneḍi.

Urbanization, agriculture, and mining activities in the upper Mogalakwena River catchment has taken place since 1960 onwards, which resulted in increased sedimentation and pollutants entering the catchment. Agriculture has increased in the Nzhelele Catchment since 1960, with instream dams also present in the Nzhelele and Ṅwaneḍi Catchments. Increased human settlements have taken place since 1960 onwards, which resulted in increased sedimentation and pollutants entering the catchments. The Nzhelele Dam was established in 1948 for irrigation purposes, which will impact the natural flow regime of the Nzhelele River, as well as the movement of biota and the transport of sediment in the system. In the Ṅwaneḍi Catchment, increased agriculture since the 1960s, with the establishment of the Ṅwaneḍi Dam in 1964 for irrigation purposes, has resulted in changes to the natural flow in the system.

The three main anthropogenic drivers of indicator status are:

- Water quality impacts due to pollutants entering the system.
- Sedimentation due to increased erosion and removal of marginal vegetation due to livestock activity at the sites.
- Changes to the natural flow patterns due to the presence of large, instream dams.

Assuming the 2023 quantity (in terms of abundance and diversity of species) of Hydropsychidae is 100%, the estimated quantity in:

c. 1900 was:

- 120% at sites 4_Mogalakwena1, 8_Nzhelele, 9_Ṅwaneḍi because very few anthropogenic impacts would have existed at this time and Hydropsychidae would have proliferated under natural to near natural conditions present in these systems.

c. 1960 was:

- 110% at sites 4_Mogalakwena1, 8_Nzhelele, 9_Ṅwaneḍi due to increased water quality impacts from anthropogenic activity in the catchments, as well as to increased sedimentation at these sites.

c. 2000 was:

- 105% at 4_Mogalakwena1, due to increased nutrients entering the system and therefore increased algal growth which has a negative impact on the benthic habitat present, as well as increased sedimentation at the sites.
- 102% at 8_Nzhelele, 9_Ṅwaneḍi due to the presence of large, instream dams which have a negative impact on the presence of Hydropsychidae, as well as to increased nutrients entering the system from anthropogenic activities in the upper catchments of these two sites.

7.4.6 Simuliidae

Relevant at EWR sites 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu.
Natural areas dominate the upper Olifantspruit, with minimal agriculture occurring since 1960 onwards, having minimal impact on the instream integrity.

Urbanization, agriculture and mining activities in the upper Mogalakwena River catchment has taken place since 1960 onwards, which resulted in increased sedimentation and pollutants entering the

catchment. There has been increased anthropogenic activity in the Nzhelele River catchment since 1960, including the presence of livestock as well as increased nutrients due to an increase in the number of human settlements in the catchment. Instream dams also contribute to changes in the natural flow regimes of these rivers. The Nzhelele Dam was established in 1948 for irrigation purposes, which will impact the natural flow regime of the Nzhelele River, as well as the movement of biota and the transport of sediment in the system. At site 10_Latonyanda, afforestation has occurred which results in increased sedimentation of benthic habitat at the site. Increased human settlements have taken place since 1960 onwards, which resulted in increased sedimentation and pollutants entering the catchment, as well as a decrease in the amount of marginal vegetation present due to increased livestock present at sites 11_Mutshindudi and 12_Luvuvhu. Two large, instream dams, the Albasini Dam, opened in 1952 and the Nanḓoni Dam opened in 2005, would have had large impacts on the natural flow in the Luvuvhu River, downstream of the dams, as well as retention of sediment in these impoundments.

The two main anthropogenic drivers of indicator status are:

- Changes in flow patterns due to the presence of large, instream dams.
- Increased sedimentation due to anthropogenic activities in the upper catchment.
- Changes to the natural water quality due to pollutants entering the system.

Assuming the 2023 quantity (in terms of abundance and diversity of species) of Simuliidae is 100%, the estimated quantity in:

c. 1900 was:

- 110% at sites 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu because very few anthropogenic impacts would have existed at this time.

c. 1960 was:

- 105% at sites 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu due to increased sedimentation and the presence of instream dams.

c. 2000 was:

- 102% at 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu due to increased sedimentation and changes to the natural flow regime of the systems.

7.4.7 Caenidae

Relevant at EWR sites 6_Kolope and 7_Sand River.

Urbanization and agriculture in the upper Sand River catchment has taken place since 1960 onwards, which resulted in increased sedimentation and pollutants entering the Sand River catchment. The Kolope River is within the Mapungubwe Reserve and will have experienced an increased pressure due to the grazing of game in the area. The presence of an upstream weir and dam which was built presumably after 2000, has a negative impact on the flow within the Kolope, downstream of the weir.

The three main anthropogenic drivers of indicator status are:

- Water quality impacts.
- Sedimentation of the benthic habitat.
- Changes in natural flow patterns due to the presence of dams and releases from sewage works.

Assuming the 2023 quantity (in terms of abundance and diversity of species) of Caenidae is 100%, the estimated quantity in:

c. 1900 was:

- 110% in 6_Kolope and 7_Sand River because very few anthropogenic impacts would have existed at this time and Caenidae would have proliferated under natural to near natural conditions present in these systems.

c. 1960 was:

- 105% in 6_Kolope and 7_Sand River. Caenidae prefer flow <0.1m/s, as well as standing water. They also favour fine sediments and are not very sensitive to changes in water quality. Therefore, they will be able to survive in the Kolope and Sand Rivers, with slightly negative responses to the naturally intermittent flow and water quality impacts since 1960 onwards. Potential pollutants from Polokwane, from 1960 onwards, due mostly to urbanization and agriculture, mostly in the upper Sand River catchment, with increased sedimentation and nutrients entering the system and having a negative impact on the instream habitat and Caenidae present.

c. 2000 was:

- 102% in 6_Kolope, because impacts present are those from an upstream dam and increased sedimentation due to the presence and concentration of game in the area due to the Mapungubwe Reserve.

7.4.8 Summary of trends

A summary of trends is given in Table 7.25.

Table 7.25: Summary of trends for macroinvertebrates

Indicator	Year	1_Lephalala	2_Rietfontein	3_Olifantspruit	4_Mogalakwena1	5_Mogalakwena2	6_Kolope	7_Sand	8_Nzhelele	9_Nwanedi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale1	14_Mutale2
Aytidae	1900										110	110	110		
	1960										105	105	105		
	2000										102	102	102		
Perlidae	1900										130	130	130	130	130
	1960										110	110	108	110	110
	2000										105	105	108	105	105
Heptageniidae	1900										130	130	130	130	130
	1960										110	110	108	110	110
	2000										105	105	108	105	105
Coenagrionidae	1900	110	110	110	110	110	115	115	110					110	110
	1960	110	110	110	110	110	105	105	110					110	110
	2000	102	102	102	102	102	102	102	102					102	102
Gomphidae	1900	110	110	110	110	110	110	110	110	110	110	110	110	110	110
	1960	108	108	108	108	108	108	108	108	108	108	108	108	108	108
	2000	105	105	105	105	105	105	105	105	105	105	105	105	105	105
Hydropsychidae	1900				120				120	120					

Indicator	Year	1_Lephalala	2_Rietfontein	3_Olifantspruit	4_Mogalakwena1	5_Mogalakwena2	6_Kolope	7_Sand	8_Nzhelele	9_Nwanedi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale1	14_Mutale2
	1960				110				110	110					
	2000				105				102	102					
Simulidae	1900			110	110	110			110		110	110	110		
	1960			105	105	105			105		105	105	105		
	2000			102	102	102			102		102	102	102		
Caenidae	1900						110	110							
	1960						105	105							
	2000						102	102							

7.5 Ecospecifications, TPCs and recommendations for monitoring

Ecological monitoring allows for the collection and assessment of ecological data. This in turn provides an indication of the ecological state or integrity of the resource and furthermore, an indication of whether management objectives are being met or not. Ecological Specifications (EcoSpecs) are broad ecological objectives that are developed for a particular resource and can be in the form of numerical values or narrative statements or both (Kleynhans & Louw, 2007). EcoSpecs are set for a specific Ecological Category. Thresholds of Potential Concern (TPCs) are usually set at the lower range of the EcoSpecs and thus function as a “red flag” or warning system that should elicit management response before ecological damage occurs. TPCs are scientific endpoints which represent probable trends or levels of undesirable change of a component within an ecosystem, which allow for an early warning or “red flag” system which will elicit an appropriate scientific and management response.

To develop and implement an effective TPC approach for a specific resource, certain criteria are required and need to be determined, including an understanding of the system for which TPCs are being developed, agents and indicators of change and limits of acceptable change. Once these criteria have been determined, TPCs can then be set for the resource.

Each site is described according to the data used, the range of SASS and ASPT scores present in the data used, the MIRAI Ecological Category percentage and reference SASS and ASPT scores.

Indicator taxa were selected according to the following criteria:

- Taxa must have a reasonably strong preference for a certain habitat type or velocity type, i.e. normally a 4 or 5 preference value (as indicated in the MIRAI), sometimes even a 3 value is used when no other appropriate taxa are present;
- Taxa must occur frequently enough i.e., a FROC (Frequency of Occurrence) value of 4 or 5, or minimally at least 50% of the time;

- Taxa should preferably be at least moderately sensitive to changes in water quality. For this study, some indicator taxa have been included that possess low sensitivity to water quality impacts because they are more relevant as indicators of habitat type.

SASS and ASPT EcoSpecs and TPCs are then determined, as well as specific EcoSpecs and TPCs for the indicator taxa. When determining the SASS and ASPT EcoSpecs and TPCs, the following should be taken into consideration:

- The data set;
- The range of present day scores;
- Outliers should be discarded;
- The median and average values for the time period should be considered;
- The present scores should be compared to the reference scores and a judgment call made in terms of the appropriate EcoSpec/TPC value.

7.5.1 Site 1_Lephalala

The predicted percentage change from PES (2022), plus Ecospecs and TPCs for 1_Lephalala are indicated in **Table 7.26** and **Table 7.27**.

Table 7.26: Macroinvertebrates: Taxon preferences for Site 1_Lephalala

Indicator	Velocity	Substrate	Quality
Heptageniidae	0.3 – 0.6m/s	Cobbles	High
Coenagrionidae	0.1-0.3m/s	Vegetation	Low
Gomphidae	0.1-0.3m/s	GSM	Low

Table 7.27: Macroinvertebrate EcoSpecs and TPCs for Site 1_Lephalala

Ecological Ecospecs	Ecological TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: >140; ASPT value: >6.1.	SASS5 scores less than 145and ASPT less than 6.3.
To ensure that the MIRAI score remains within the range of a B/C category (>78 - ≤82 %), using the same reference data used in this study.	A MIRAI score of 79% or less.
To maintain suitable flow velocity (>0.6m/s) and to maintain clean, unembedded surface area (cobbles) to support the following flow-dependent taxa: Heptageniidae (Abundance A)	If Heptageniidae is missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain sufficient quantity and quality of inundated vegetation to support the following vegetation-dwelling taxon: Coenagrionidae (Abundance A)	Coenagrionidae missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain suitable conditions for the following three key taxa: Heptageniidae Coenagrionidae Gomphidae	Presence of less than two of the three key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as C abundance (>100) over more than two consecutive surveys.	Any taxon occurring in an abundance of >100 for two consecutive surveys.

7.5.2 Site 2_Rietfontein

This site is situated in a spring-fed drainage line, with no SASS able to be conducted, thus EcoSpecs can be set for suitable aquatic habitat only (**Table 7.28**).

Table 7.28: Macroinvertebrate EcoSpecs and TPCs for Site 2_Rietfontein

Ecological Ecospecs	Ecological TPCs
To maintain sufficient quantity and quality of inundated vegetation to support the following vegetation-dwelling taxon: Coenagrionidae (Abundance A)	Coenagrionidae missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain suitable conditions for the following two key taxa: Coenagrionidae Gomphidae	Presence of less than one of the two key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as C abundance (>100) over more than two consecutive surveys.	Any taxon occurring in an abundance of >100 for two consecutive surveys.

7.5.3 Site 3_Olifantspruit

The predicted percentage change from PES (2022), plus Ecospecs and TPCs for 3_Olifantspruit are indicated in **Table 7.29** and **Table 8.30.**

Table 7.29: Macroinvertebrates: Taxon preferences for Site 3_Olifantspruit

Indicator	Velocity	Substrate	Quality
Simuliidae	> 0.6m/s	Cobbles	Low
Coenagrionidae	0.1-0.3m/s	Vegetation	Low
Gomphidae	0.1-0.3m/s	GSM	Low

Table 7.30: Macroinvertebrate EcoSpecs and TPCs for Site 3_Olifantspruit

Ecological Ecospecs	Ecological TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: >140; ASPT value: >6.0	SASS5 scores less than 145 and ASPT less than 6. 1.
To ensure that the MIRAI score remains within the range of a B/C category (>78 - ≤82 %), using the same reference data used in this study.	A MIRAI score of 79% or less.
To maintain suitable flow velocity (>0.6m/s) and to maintain clean, unembedded surface area (cobbles) to support the following flow-dependent taxa: Simuliidae (Abundance A)	If Simuliidae is missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain sufficient quantity and quality of inundated vegetation to support the following vegetation-dwelling taxon: Coenagrionidae (Abundance A)	Coenagrionidae missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain suitable conditions for the following three key taxa: Simuliidae Coenagrionidae Gomphidae	Presence of less than two of the three key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as C abundance (>100) over more than two consecutive surveys.	Any taxon occurring in an abundance of >100 for two consecutive surveys.

7.5.4 Site 4_Mogalakwena1

The predicted percentage change from PES (2022), plus Ecospecs and TPCs for 4_Mogalakwena1 are indicated in **Table 7.31** and **Table 7.32**

Table 7.31: Macroinvertebrates: Taxon preferences for Site 4_Mogalakwena1.

Indicator	Velocity	Substrate	Quality
Hydropsychidae	> 0.6m/s	Cobbles	High
Simuliidae	> 0.6m/s	Cobbles	Low
Coenagrionidae	0.1-0.3m/s	Vegetation	Low
Gomphidae	0.1-0.3m/s	GSM	Low

Table 7.32: Macroinvertebrate EcoSpecs and TPCs for Site 4_Mogalakwena1.

Ecological Ecospecs	Ecological TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: >130; ASPT value: >6.3.	SASS5 scores less than 135 and ASPT less than 6.5.
To ensure that the MIRAI score remains within the range of a C category (>62 - ≤78 %), using the same reference data used in this study.	A MIRAI score of 64% or less.
To maintain suitable flow velocity (>0.6m/s) and to maintain clean, unembedded surface area (cobbles) to support the following flow-dependent taxa: Hydropsychidae >2pp (Abundance A) Simuliidae (Abundance A)	If Simuliidae is missing in two consecutive surveys or has a single individual present in two consecutive surveys. If Hydropsychidae has <2spp present in two consecutive surveys.
To maintain sufficient quantity and quality of inundated vegetation to support the following vegetation-dwelling taxon: Coenagrionidae (Abundance A)	Coenagrionidae missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain suitable conditions for the following four key taxa: Hydropsychidae Simuliidae Coenagrionidae Gomphidae	Presence of less than three of the four key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as C abundance (>100) over more than two consecutive surveys.	Any taxon occurring in an abundance of >100 for two consecutive surveys.

7.5.5 Site 5_Mogalakwena2

The predicted percentage change from PES (2022), plus Ecospecs and TPCs for 5_Mogalakwena2 are indicated in **Table 7.33** and **Table 7.34**

Table 7.33: Macroinvertebrates: Taxon preferences for Site 5_Mogalakwena2.

Indicator	Velocity	Substrate	Quality
Simuliidae	> 0.6m/s	Cobbles	Low
Coenagrionidae	0.1-0.3m/s	Vegetation	Low
Gomphidae	0.1-0.3m/s	GSM	Low

Table 7.34: Macroinvertebrate EcoSpecs and TPCs for Site 5_Mogalakwena2.

Ecological Ecospecs	Ecological TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: >120; ASPT value: >5.3.	SASS5 scores less than 125 and ASPT less than 5.5.
To ensure that the MIRAI score remains within the range of a C category (>62 - ≤78 %), using the same reference data used in this study.	A MIRAI score of 64% or less.
To maintain suitable flow velocity (>0.6m/s) and to maintain clean, unembedded surface area (cobbles) to support the following flow-dependent taxa: Simuliidae (Abundance A)	If Simuliidae is missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain sufficient quantity and quality of inundated vegetation to support the following vegetation-dwelling taxon: Coenagrionidae (Abundance A)	Coenagrionidae missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain suitable conditions for the following three key taxa: Simuliidae Coenagrionidae Gomphidae	Presence of less than two of the three key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as C abundance (>100) over more than two consecutive surveys.	Any taxon occurring in an abundance of >100 for two consecutive surveys.

7.5.6 Site 6_Kolope

EcoSpecs can be set for suitable aquatic habitat only (when surface water is present), no SASS data is available for this site (**Table 7.35**).

Table 7.35: Macroinvertebrate EcoSpecs and TPCs for Site 6_Kolope

Ecological Ecospecs	Ecological TPCs
To maintain sufficient quantity and quality of inundated vegetation to support the following vegetation-dwelling taxon: Coenagrionidae (Abundance A)	Coenagrionidae missing in two consecutive surveys, or has a single individual present in two consecutive surveys.
To maintain suitable conditions for the following three key taxa: Coenagrionidae Gomphidae Caenidae	Presence of less than two of the three key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as C abundance (>100) over more than two consecutive surveys.	Any taxon occurring in an abundance of >100 for two consecutive surveys.

7.5.7 Site 7_Sand

EcoSpecs can be set for suitable aquatic habitat only (when surface water is present), no SASS data is available for this site (**Table 7.36**).

Table 7.36: Macroinvertebrate EcoSpecs and TPCs for Site 7_Sand

Ecological Ecospecs	Ecological TPCs
To maintain sufficient quantity and quality of inundated vegetation to support the following vegetation-dwelling taxon: Coenagrionidae (Abundance A)	Coenagrionidae missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain suitable conditions for the following three key taxa: Coenagrionidae Gomphidae Caenidae	Presence of less than two of the three key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as C abundance (>100) over more than two consecutive surveys.	Any taxon occurring in an abundance of >100 for two consecutive surveys.

7.5.8 Site 8_Nzhelele

The predicted percentage change from PES (2022), plus Ecospecs and TPCs for 8_Nzhelele are indicated in **Table 7.37** and **Table 7.38**

Table 7.37: Macroinvertebrates: Taxon preferences for Site 8_Nzhelele.

Indicator	Velocity	Substrate	Quality
Hydropsychidae	> 0.6m/s	Cobbles	High
Simuliidae	> 0.6m/s	Cobbles	Low
Coenagrionidae	0.1-0.3m/s	Vegetation	Low
Gomphidae	0.1-0.3m/s	GSM	Low

Table 7.38: Macroinvertebrate EcoSpecs and TPCs for Site 8_Nzhelele.

Ecological Ecospecs	Ecological TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: >130; ASPT value: >6.0.	SASS5 scores less than 135 and ASPT less than 6. 2.
To ensure that the MIRAI score remains within the range of a B/C category (>78 - ≤82 %), using the same reference data used in this study.	A MIRAI score of 79% or less.
To maintain suitable flow velocity (>0.6m/s) and to maintain clean, unembedded surface area (cobbles) to support the following flow-dependent taxa: Hydropsychidae >2pp (Abundance A) Simuliidae (Abundance A)	If Simuliidae is missing in two consecutive surveys or has a single individual present in two consecutive surveys. If Hydropsychidae has <2spp present in two consecutive surveys.
To maintain sufficient quantity and quality of inundated vegetation to support the following vegetation-dwelling taxon: Coenagrionidae (Abundance A)	Coenagrionidae missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain suitable conditions for the following four key taxa: Hydropsychidae Simuliidae Coenagrionidae Gomphidae	Presence of less than three of the four key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as C abundance (>100) over more than two consecutive surveys.	Any taxon occurring in an abundance of >100 for two consecutive surveys.

7.5.9 Site 9_ Ṅwaneḍi

The predicted percentage change from PES (2022), plus Ecospecs and TPCs for 9_Ṅwaneḍi are indicated in **Table 7.39** and **Table 7.40**

Table 7.39: Macroinvertebrates: Taxon preferences for Site 9_Ṅwaneḍi

Indicator	Velocity	Substrate	Quality
Hydropsychidae	> 0.6m/s	Cobbles	High
Gomphidae	0.1-0.3m/s	GSM	Low

Table 7.40: Macroinvertebrate EcoSpecs and TPCs for Site 9_Ṅwaneḍi.

Ecological Ecospecs	Ecological TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: >110; ASPT value: >6.1.	SASS5 scores less than 115 and ASPT less than 6. 3.
To ensure that the MIRAI score remains within the range of a C category (>62 - ≤78 %), using the same reference data used in this study.	A MIRAI score of 64% or less.
To maintain suitable flow velocity (>0.6m/s) and to maintain clean, unembedded surface area (cobbles) to support the following flow-dependent taxa: Hydropsychidae (Abundance A)	Hydropsychidae is missing in two consecutive surveys.
To maintain suitable conditions for the following two key taxa: Hydropsychidae Gomphidae	Presence of less than one of the two key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as C abundance (>100) over more than two consecutive surveys.	Any taxon occurring in an abundance of >100 for two consecutive surveys.

7.5.10 Site 10_Latonyanda

The predicted percentage change from PES (2022), plus Ecospecs and TPCs for 10_Latonyanda are indicated in **Table 7.41** and **Table 7.42**.

Table 7.41: Macroinvertebrates: Taxon preferences for Site 10_Latonyanda

Indicator	Velocity	Substrate	Quality
Heptageniidae	0.3 – 0.6m/s	Cobbles	High
Simuliidae	> 0.6m/s	Cobbles	Low
Atyidae	<0.1m/s	Vegetation	Moderate
Gomphidae	0.1-0.3m/s	GSM	Low

Table 7.42: Macroinvertebrate EcoSpecs and TPCs for Site 10_Latonyanda

Ecological Ecospecs	Ecological TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: >175; ASPT value: >7.1.	SASS5 scores less than 180 and ASPT less than 7. 3.
To ensure that the MIRAI score remains within the range of a B/C category (>78 - ≤82 %), using the same reference data used in this study.	A MIRAI score of 79% or less.
To maintain suitable flow velocity (>0.6m/s) and to maintain clean, unembedded surface area (cobbles) to support the following flow-dependent taxa: Heptageniidae (Abundance A) Simuliidae (Abundance A)	If Heptageniidae or Simuliidae is missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain sufficient quantity and quality of inundated vegetation to support the following vegetation-dwelling taxon: Atyidae (Abundance A)	Atyidae missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain suitable conditions for the following four key taxa: Heptageniidae Simuliidae Atyidae	Presence of less than three of the four key taxa listed in any survey.

Ecological Ecospecs	Ecological TPCs
Gomphidae	
To ensure that no group consistently dominates the fauna, defined as C abundance (>100) over more than two consecutive surveys.	Any taxon occurring in an abundance of >100 for two consecutive surveys.

7.5.11 Site 11_ Mutshindudi

The predicted percentage change from PES (2022), plus Ecospecs and TPCs for 11_Mutshindudi are indicated in **Table 7.43** and **Table 7.44**.

Table 7.43: Macroinvertebrates: Taxon preferences for Site 11_Mutshindudi

Indicator	Velocity	Substrate	Quality
Heptageniidae	0.3 – 0.6m/s	Cobbles	High
Simuliidae	> 0.6m/s	Cobbles	Low
Atyidae	<0.1m/s	Vegetation	Moderate
Gomphidae	0.1-0.3m/s	GSM	Low

Table 7.44: Macroinvertebrate EcoSpecs and TPCs for Site 11_Mutshindudi

Ecological Ecospecs	Ecological TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: >160; ASPT value: >6.8.	SASS5 scores less than 165 and ASPT less than 7. 0.
To ensure that the MIRAI score remains within the range of a C category (>62 - ≤78 %), using the same reference data used in this study.	A MIRAI score of 64% or less.
To maintain suitable flow velocity (>0.6m/s) and to maintain clean, unembedded surface area (cobbles) to support the following flow-dependent taxa: Heptageniidae (Abundance A) Simuliidae (Abundance A)	If Heptageniidae or Simuliidae is missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain sufficient quantity and quality of inundated vegetation to support the following vegetation-dwelling taxon: Atyidae (Abundance A)	Atyidae missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain suitable conditions for the following four key taxa: Heptageniidae Simuliidae Atyidae Gomphidae	Presence of less than three of the four key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as C abundance (>100) over more than two consecutive surveys.	Any taxon occurring in an abundance of >100 for two consecutive surveys.

7.5.12 Site 12_Luvuvhu

The predicted percentage change from PES (2022), plus Ecospecs and TPCs for 12_Luvuvhu are indicated in **Table 7.45** and **Table 7.46**.

Table 7.45: Macroinvertebrates: Taxon preferences for Site 12_Luvuvhu

Indicator	Velocity	Substrate	Quality
Perlidae	0.3 – 0.6m/s	Cobbles	High
Simuliidae	> 0.6m/s	Cobbles	Low
Atyidae	<0.1m/s	Vegetation	Moderate
Gomphidae	0.1-0.3m/s	GSM	Low

Table 7.46: Macroinvertebrate EcoSpecs and TPCs for Site 12_Luvuvhu

Ecological Ecospecs	Ecological TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: >160; ASPT value: >5.7.	SASS5 scores less than 165 and ASPT less than 5.9.
To ensure that the MIRAI score remains within the range of a B/C category (>78 - ≤82 %), using the same reference data used in this study.	A MIRAI score of 79% or less.
To maintain suitable flow velocity (>0.6m/s) and to maintain clean, unembedded surface area (cobbles) to support the following flow-dependent taxa: Perlidae (Abundance A) Simuliidae (Abundance A)	If Perlidae or Simuliidae is missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain sufficient quantity and quality of inundated vegetation to support the following vegetation-dwelling taxon: Atyidae (Abundance A)	Atyidae missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain suitable conditions for the following four key taxa: Perlidae Simuliidae Atyidae Gomphidae	Presence of less than three of the four key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as C abundance (>100) over more than two consecutive surveys.	Any taxon occurring in an abundance of >100 for two consecutive surveys.

7.5.13 Site 13_Mutale1

The predicted percentage change from PES (2022), plus Ecospecs and TPCs for 13_Mutale1 are indicated in Table **7.48**.

Table 7.47: Macroinvertebrates: Taxon preferences for Site 13_Mutale1

Indicator	Velocity	Substrate	Quality
Heptageniidae	0.3 – 0.6m/s	Cobbles	High
Coenagrionidae	0.1-0.3m/s	Vegetation	Low

Table 7.48: Macroinvertebrate EcoSpecs and TPCs for Site 13_Mutale1

Ecological Ecospecs	Ecological TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: >160; ASPT value: >6.0.	SASS5 scores less than 165 and ASPT less than 6.2.
To ensure that the MIRAI score remains within the range of a C category (>62 - ≤78 %), using the same reference data used in this study.	A MIRAI score of 64% or less.
To maintain suitable flow velocity (>0.6m/s) and to maintain clean, unembedded surface area (cobbles) to support the following flow-dependent taxa: Heptageniidae (Abundance A)	If Heptageniidae is missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain sufficient quantity and quality of inundated vegetation to support the following vegetation-dwelling taxon: Coenagrionidae (Abundance A)	Coenagrionidae missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain suitable conditions for the following two key taxa: Heptageniidae Coenagrionidae Gomphidae	Presence of less than one of the two key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as C abundance (>100) over more than two consecutive surveys.	Any taxon occurring in an abundance of >100 for two consecutive surveys.

7.5.14 Site 14_Mutale2

The predicted percentage change from PES (2022), plus Ecospecs and TPCs for 14_Mutale2 are indicated in **Table 7.49** and **Table 7.50.**

Table 7.49: Macroinvertebrates: Taxon preferences for Site 14_Mutale2

Indicator	Velocity	Substrate	Quality
Perlidae	0.3 – 0.6m/s	Cobbles	High
Heptageniidae	0.3 – 0.6m/s	Cobbles	High
Coenagrionidae	0.1-0.3m/s	Vegetation	Low
Gomphidae	0.1-0.3m/s	GSM	Low

Table 7.50: Macroinvertebrate EcoSpecs and TPCs for Site 14_Mutale2

Ecological Ecospecs	Ecological TPCs
To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score: >130; ASPT value: >6.0.	SASS5 scores less than 135 and ASPT less than 6.2.
To ensure that the MIRAI score remains within the range of a C category (>62 - ≤78 %), using the same reference data used in this study.	A MIRAI score of 64% or less.
To maintain suitable flow velocity (>0.6m/s) and to maintain clean, unembedded surface area (cobbles) to support the following flow-dependent taxa: Perlidae (Abundance A) Heptageniidae (Abundance A)	If Perlidae or Heptageniidae is missing in two consecutive surveys or has a single individual present in two consecutive surveys.
To maintain sufficient quantity and quality of inundated vegetation to support the following vegetation-dwelling taxon:	Coenagrionidae missing in two consecutive surveys or has a single individual present in two consecutive surveys.

Ecological Ecospecs	Ecological TPCs
Coenagrionidae (Abundance A)	
To maintain suitable conditions for the following four key taxa: Perlidae Heptageniidae Coenagrionidae Gomphidae	Presence of less than three of the four key taxa listed in any survey.
To ensure that no group consistently dominates the fauna, defined as C abundance (>100) over more than two consecutive surveys.	Any taxon occurring in an abundance of >100 for two consecutive surveys.

7.6 Monitoring recommendations

Sampling using the latest SASS (South African Scoring System) protocol is suggested, on a quarterly basis as part of REMP monitoring. Monitoring should only be conducted by a DWS accredited practitioner. REMP (River Ecostatus Monitoring Programme) regional monitoring, conducted by the DWS regional officials, should continue at their existing sites and monitoring frequencies, which will overlap with the recommendations for the Reserve monitoring of the Reserve sites.

8 FISH

8.1 Introduction

The main objective of the fish study was to identify the relationship between fish and flow level changes, and to predict what impacts, if any, will occur with changes to the PES (2022) flow regime.

8.1.1 Assumptions and limitations

The success of catching fish is affected by prevailing weather and flow and recent flow events. Fish diversity and abundances are also different when fish are migrating. There was limited sampling time so several methods could not be used, such as gill nets and fish traps. Electrofishing and cast nets were used. Whatever methods used, catching no fish does not mean there were no fish to catch, rather the fish were not 'biting' or evaded capture. In these instances, historical reference data were used for the species expected to occur based on the quality and variety of fish habitats present. When scoring in FRAI (Kleynhans 2007), this meant that where catches were low, high deviation from reference was scored.

8.2 EWR sites with a focus on fish

8.2.1 Catchment description

The Limpopo River Basin includes an area of approximately 415,000 km^2 that spans across four countries, namely South Africa, Botswana, Zimbabwe, and Mozambique. Although many of its tributaries are regarded as being perennial, the Limpopo River itself is a non-perennial system, with the subterranean movement of water through deep gravel beds dominating the flow patterns of the river during the drier winter season. Gaigher (1973) surveyed 220 sites in the South African portion of the Limpopo River basin and grouped his fish assemblages into three habitat types, perennial rapids, perennial and seasonal pools, being more important than substrate type or the presence of aquatic plants. There are 59 species in 13 families (**Figure 8.1**), the most dominant being Cyprinidae (24 species), Cichlidae (6 species), Mochokidae and Mormyridae (both 5 species)

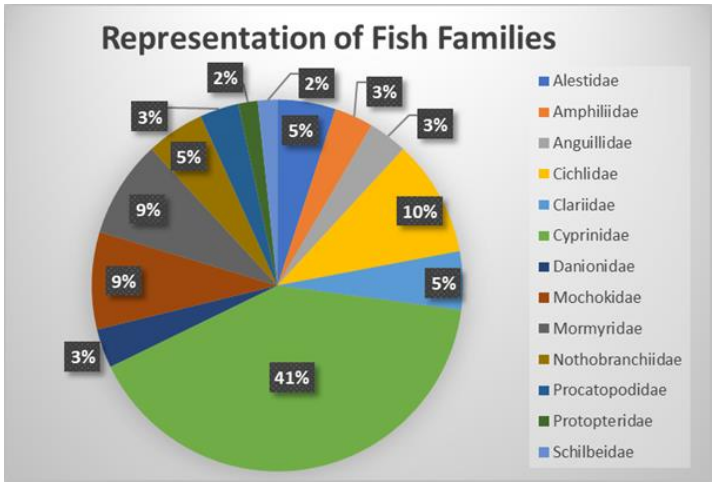


Figure 8.1: Fish families in the Limpopo River basin

8.2.2 Data collection and analysis

Species lists of fish expected to occur were compiled from a range of sources, some new and some old:

- Kruger National Park
- FRAI (Kleynhans 2007)
- PES/EIS data base (DWS 2014)
- Field guides; Scott et al. (2006), Skelton (2001), Pienaar (1968)
- Unofficial datasets from colleagues
- Freshwater Biodiversity Information System (FBIS, https://freshwaterbiodiversity.org)
- FishBase (http://www.fishbase.se).

Electro-shocking and seine nets were used to fish at each EWR site on a low (August 2022) and a high (May 2023) flow field trip. Fish habitat was assessed following the FRAI methods of Kleynhans (2007):

- Habitat potential; abundance of flow-depth classes (slow-deep, slow-shallow, fast-deep and fast-shallow), the presence or absence of aquatic and overhanging vegetation, and substratum type.
- Habitat condition, relative to the undisturbed nature of habitats expected.

The fish data collected per site were separated out into those species that are known to have a propensity for the various velocity-depth classes and frequency of occurrence calculated and entered into the FRAI database. The observed data were compared to the expected species lists to generate a percentage score and Ecological Category at each EWR site by considering and scoring impacts related to:

- Flow-depth classes
- Cover (overhanging vegetation, undercut banks, substratum type, aquatic vegetation and sedimentation)
- Flow modification
- Water quality modification
- Barriers to migration
- The presence of exotic fish species.

8.2.3 Description of sites

8.2.3.1 1_Lephalala

1_Lepahala was a multi-channelled and braided watercourse with a deep pool upstream and a small floodplain on the right bank. The in-channel habitats comprised fast-shallow and fast-deep flow over bedrock, boulders and larger cobble, and backwaters with slow-shallow flow over cobble and fines, which were limited and comprised gravel, sand and silt (**Figure 8.2**). The braided channel comes into a single channel downstream dominated by fast-deep flow. The marginal vegetation comprised sedges and reeds.

The water and habitat quality were good but the catch was poor, there were three species and a total of 38 individuals captured (**Table 8.1**) during the low flow survey. This could be explained by the severe drought from 1980 – 1990 that decimated fish populations (pers. comm. C. Kleynhans) and the many irrigation weirs downstream to the Limpopo River, which would have hindered fish recruitment into 1_Lephalala from the Limpopo River. The fish that were caught (*Chiloglanis pretoriae, Labeobarbus marequensis* and *Labeo cylindricus)* were all strong swimmers known to have the ability to navigate

difficult hydraulic conditions and have a higher success rate of succeffully navigating migratory barriers whereas other species cannot (pers obs).

There were fewer fish caught during the high flow survey (**Table 8.2**); *Labeo cylindricus* was not caught during the high flow season, and *Clarias gariepinus* was not caught during the low flow season. Both of these species are widespread within the Limpopo basin, and their absence during the respective surveys tends to be indicative of an external driver of ecological change, especially as both species were noted to be relatively common during both surveys. *Chiloglanis pretoriae* was noted as being the most abundant fish.



A slow-deep habitat in a side channel on the right bank.



Large cobbles and boulders, with the interstitial spaces as refuge for small fish.



A quieter backwater zone with slow-shallow flow over cobbles.



The single channel downstream of the braided section.

Figure 8.2: Fish habitat at 1_Lephalala

Table 8.1: Fish and habitat data at 1_Lephalala (low flow)[4]

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
90min	x25			11	11	61	17	OH Veg	3	3	3	3
Equipment details (mesh size, etc):								Aq Veg	0	0	0	1
Electro-fisher	SAMUS battery backpack & 1kVa generator unit							UC banks & root wads	3	2	2	3
Cast net	20mm, 6 ft							Substrate	3	3	4	4
Seine net	-							Water column	3	4	2	2

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Chiloglanis pretoriae	20			17	3						
Labeo cylindricus	5	2		3							
Labeobarbus marequensis	13	3	1	7	2						
TOTAL ABUNDANCE:	38	5	1	27	5						

Table 8.2: Fish and habitat data at 1_Lephalala (high flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
60min				5	10	55	40	OH Veg	2	3	3	3
Equipment details (mesh size, etc):								Aq Veg	0	1	0	1
Electro-fisher	SUM battery backpack 1200v							UC banks & root wads	3	2	2	1
Cast net	-							Substrate	3	3	4	4
Seine net	-							Water column	3	4	2	2

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Labeobarbus marequensis	1				1						
Chiloglanis pretoriae	9			9							
Clarias gariepinus	1				1						
TOTAL ABUNDANCE:	11	0	0	9	2						

The FRAI score was 34.8%, an **E** category **(Table 8.3**). This poor score reflects that the fish expected to occur in the variety of velocity-depths and the abundant and various habitats were absent, largely due to the migration barriers preventing their recolonization of 1_Lephalala after the drought in the 1980s. Flow and water quality were scored lower than natural.

[4] El-F = electro-fishing effort, C-Net = cast net, S-Ns (Nb) = seine net small (big) gauge, Vel_= velocity, FD = fast deep, SD = slow deep, FS = fast shallow, SS = slow shallow, Hab = habitat, OH Veg = overhanging vegetation, Aq Veg = aquatic vegetation, UC = undercut, V-D = velocity depth.

Table 8.3: FRAI results for 1_Lephalala

Habitat metric	% deviation from natural	Overall % impact on fish assemblage
Velocity Depth classes	0.0%	80.0%
Cover	0.0%	86.1%
Flow modifications	35.6%	79.4%
Physico-chemical	35.4%	82.8%
Migrations	-	80.0%
Introduction of alien species	-	0.0%
Introduced & translocated species	-	0.0%
FRAI Score (automated)	18.2%	E/F
FRAI Score (adjusted)	34.8%	**E**

8.2.3.2 2_Rietfontein

There was a small channel at 2_Rietfontein that was fed from a groundwater spring. There were some permanent bedrock pools and a small dam. The channel comprised coarse-grained gravels and there was no flow connecting this to the Limpopo River; surface flow percolated into the alluvial sand downstream effectively creating a migration barrier. The riparian vegetation was marginal grasses and sedges, and there were riparian trees upslope (**Figure 8.3**).

There was little water to sample at low flow and no fish were observed. A healthy and productive breeding population of 23 *Oreochromis mossambicus* with a high diversity of age and size classes were captured at high flow (**Table 8.4**). They are tolerant of high salinity and there was very high electrical conductivity recorded (~2500 µS/cm).



The watercourse through the valley bottom wetland.



Marginal grasses and sedges and riparian trees.



The small impoundment.



Bedrock pools.

Figure 8.3: Fish habitat at 2_Rietfontein

Table 8.4: Fish and habitat data at 2_Rietfontein (high flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
	X10			-	50	-	50	OH Veg	0	2	0	1
Equipment details (mesh size, etc):								Aq Veg	0	1	0	1
Electro-fisher	-							UC banks & root wads	0	2	0	1
Cast net	20mm, 6 ft							Substrate	0	1	0	1
Seine net	-							Water column	0	4	0	1

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Oreochromis mossambicus	23		7		16						
TOTAL ABUNDANCE:	23		7		16						

The FRAI score was 100%, an **A** category (**Table 8.5**) because the only species expected to occur in this high salinity groundwater fed channel was *Oreochromis mossambicus* so there were no exclusions between the reference and PES (2022) data.

Table 8.5: FRAI results for 2_Rietfontein

Habitat metric	% deviation from natural	Overall % impact on fish assemblage
Velocity Depth classes	0.0%	0.0%
Cover	0.0%	0.0%
Flow modifications	0.0%	0.0%
Physico-chemical	0.0%	0.0%
Migrations	0.0%	0.0%
Introduction of alien species	0.0%	0.0%
Introduced & translocated species	0.0%	0.0%
FRAI Score (automated)	100.0%	A
FRAI Score (adjusted)	100.0%	**A**

8.2.3.3 3_Olifantspruit

The river at 3_Olifantspruit was a narrow single channel upstream of the bridge with fast-shallow riffles and slow-shallow runs **(Figure 8.4**) over cobbles and gravel respectively, with some sands and mud on the edges where grasses, reeds and sedges were growing. Downstream of the bridge there were two channels, one shallower enclosed with reeds and the other a deeper run at the bridge with riffles further downstream and marginal reeds on both banks.



Fast-shallow flowing riffles.



Marginal vegetation downstream of the bridge.



Slow-deep flow through a run.



Large woody debris under the bridge.

Figure 8.4: Fish habitat at 3_Olifantspruit

The river comprised shallow riffles at low flow where smaller-bodied and bottom dwelling fish were caught and a deep pool upstream with a large number of *Labeobarbus marequensis* (**Table 8.6**). There was relatively good species diversity with five species and an abundance of 79 fish during the low flow survey.

Table 8.6: Fish and habitat data at 3_Olifantspruit (low flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
	X20			-	50	-	50	OH Veg	0	3	3	2
Equipment details (mesh size, etc):								Aq Veg	0	0	0	0
Electro-fisher	-							UC banks & root wads	0	3	3	3
Cast net	20mm, 6 ft							Substrate	0	3	4	3
Seine net	-							Water column	0	4	2	2

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Chiloglanis pretoriae	17			17		*Enteromius paludinosus*	3			2	1
Amphilius uranoscopus	6			6		*Chetia flaviventris*	4		2		2
Labeobarbus marequensis	34		27	7		*Pseudocrenilabrus philander*	1				1
Labeo cylindricus	3			3		*Tilapia sparrmanii*	2		2		
Enteromius unitaeniatus	9		6	3							
TOTAL ABUNDANCE:	79	-	37	38	4						

The number of species and individuals caught at high flow was similar but the species differed (**Table 8.7**). The dominant fish was still *Labeobarbus marequensis* in the pools and riffles as before, and then *Enteromius paludinosus* in the slower flowing marginally vegetated sections. *Chiloglanis pretoriae* is a sedentary sucker-mouth catfish that exhibits little migratory habits so its absence from the riffle habitat was unexpected. A species of fish being present and then absent on consecutive surveys is not however uncommon.

Table 8.7: Fish and habitat data at 3_Olifantspruit (high flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
65min				0	10	70	20	OH Veg	0	0	4	3
Equipment details (mesh size, etc):								Aq Veg	0	0	3	2
Electro-fisher	SUM battery backpack 1200v							UC banks & root wads	0	1	2	1
Cast net								Substrate	0	2	3	3
Seine net	-							Water column	0	4	2	1

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Labeobarbus marequensis	27		13	12	2	*Pseudocrenilabrus philander*	8		2		6
Enteromius bifrenatus	4			1	3	*Tilapia sparrmanii*	6		4	1	1
Enteromius unitaeniatus	1			1		*Clarias gariepinus*	1		1		
Enteromius paludinosus	24			5	19	*Enteromius radiatus*	2			2	
Chetia flaviventris	3				3						
TOTAL ABUNDANCE:	76	-	20	22	34						

The FRAI score was 79.3%, a **B/C** category (**Table 8.8**), where there where some water quality and flow modifications scored and there were differences in the expected versus observed fish catch.

Table 8.8: FRAI results for 3_Olifantspruit

Habitat metric	% deviation from natural	Overall % impact on fish assemblage
Velocity Depth classes	7.8%	25.1%
Cover	24.6%	14.4%
Flow modifications	35.6%	26.5%
Physico-chemical	29.9%	29.1%
Migrations	0.0%	0.0%
Introduction of alien species	0.0%	0.0%
Introduced & translocated species	0.0%	0.0%
FRAI Score	79.3%	**B/C**

8.2.3.4 4_Mogalakwena1

4_Mogalakwena1 was downstream of the confluence of the Mogalakwena and Sterk Rivers. There were riffles with fast-shallow flow over cobble and gravels (**Figure 8.5**) and some deeper slower flowing pools; the riffle-pool combination alternated repeatedly downstream. There was a high vertical bank downstream where some trees had fallen into the river that provided valuable large woody debris habitat but also resulted in there being a large amount of fine sediment in the pool and on the point bar. The riparian zone comprised grasses, shrubs and trees on the right bank and marginal reeds in the channel and on the flood terraces on the left bank. There was a high level of disturbance to the channel banks and bed from the causeway crossing and because of livestock being watered in the river.



A slow-deep pool.



Fast-shallow flow through a riffle-run.



Cobbles and gravels on the channel bed.



Undercut banks and overhanging vegetation.

Figure 8.5: Fish habitat at 4_Mogalakwena1

A cast net was used to catch six *Micralestes acutidens* in the slow-deep pool of the river during the low flow survey. There were ten species and 43 fish caught during the high flow survey (**Table 8.9**), a good representation of species from different families with none showing dominance over the others. There were more smaller-bodied fish than larger, which was expected, and a good balance of migratory and sedentary fish indicating good passage between 4_Mogalakwena1 and the river downstream.

Table 8.9: Fish and habitat data at 4_Mogalakwena (high flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
65min				0	20	70	10	OH Veg	1	3	3	3
Equipment details (mesh size, etc):								Aq Veg	0	0	0	0
Electro-fisher	SUM 1200v battery backpack Electro-fisher							UC banks & root wads	0	1	2	1
Cast net	-							Substrate	2	2	3	3
Seine net	-							Water column	3	4	1	2

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Labeobarbus marequensis	6	2		3	1	*Pseudocrenilabrus philander*	4				4
Enteromius trimaculatus	9				9	*Tilapia sparrmanii*	3		1		2
Micralestes acutidens	2				2	*Clarias gariepinus*	4		2		2
Enteromius paludinosus	5			2	3	*Enteromius radiatus*	2			2	
Micropanchax johnstoni	1		1			*Chiloglanis pretoriae*	7	3		4	
TOTAL ABUNDANCE:	23	2	1	5	15		20	3	3	6	8

The FRAI score was 72.9%, a **C** category (**Table 8.10**), driven by changes in habitat cover, velocity-depth classes because of flow modification by upstream dams, and water quality alterations, from mining upstream. Despite the good diversity at this site there were still some fish missing that were expected to occur that brought the score down further.

Table 8.10: FRAI results for 4_Mogalakwena1

Habitat metric	% deviation from natural	Overall % impact on fish assemblage
Velocity Depth classes	13.5%	32.6%
Cover	19.3%	40.7%
Flow modifications	41.6%	18.4%
Physico-chemical	35.0%	25.0%
Migrations	-	19.0%
Introduction of alien species	0%	0%
Introduced & translocated species	0%	0%
FRAI Score	72.9%	**C**

8.2.3.5 5_Mogalakwena2

5_Mogalakwena2 was a wide river with a diversity of fish habitat. There were slow-shallow flow areas along the right bank over cobbles, boulders, gravel and fine-grained sand where emergent sedges were growing. The thalweg was fast-shallow riffles or fast-deep runs over boulders and cobbles. There were

more sheltered areas on the left bank with much marginal and overhanging vegetation and slower flowing sections upstream with sands, mud and large woody debris (**Figure 8.6**).

Cast nets were used to catch seven species and 94 fish during low flow **(Table 8.11)**, which was a good representative sample from the diversity of habitats present. *Labeobarbus marequensis* and *Labeo cylindricus* dominated the fast flowing habitats, as expected, and the slow flowing areas on bedrock and silt was where the cichlids were found.



Runs and riffles with fast-shallow and fast-deep flow, and slow-shallow flow on the edges of the channel.



Vegetated gravel bars and slow-shallow flow on the right bank.



An overview of 5_Mogalakwena2.



Overhanging and emergent vegetation in the side channels.

Figure 8.6: Fish habitat at 5_Mogalakwena2

Table 8.11: Fish and habitat data at 5_Mogalakwena (low flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
-	X50							OH Veg	0	2	1	1
Equipment details (mesh size, etc):								Aq Veg	0	0	0	0
Electro-fisher								UC banks & root wads	0	2	1	1
Cast net	6ft, 20mm							Substrate	2	3	3	3
Seine net	-							Water column	3	4	1	2

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Engraulicypris brevianalis	1			1		*Oreochromis mossambicus*	22		17		5
Labeobarbus marequensis	19			17	2	*Pseudocrenilabrus philander*	2		2		
Labeo cylindricus	14			14		*Coptodon rendalli*	27		27		
Micralestes acutidens	9			7	2						
TOTAL ABUNDANCE:	94	-	46	39	9						

There were 13 species and 133 fish caught at during the high flow survey (**Table 8.12**), a very good result but again not unexpected from the high diversity of good quality habitat. *Labeobarbus marequensis, Labeo cylindricus* and *Labeo molybdinus* were found in the fast deep habitats on boulders and cobbles and the smaller bodied fish were found in fast shallow habitats on cobbles and gravels. There was good spawning habitat of coarse-grained sediments free from debris and silt.

Table 8.12: Fish and habitat data at 5_Mogalakwena (high flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
120m in				15 %	5%	45 %	35 %	OH Veg	0	3	4	4
Equipment details (mesh size, etc):								Aq Veg	0	1	2	2
Electro-fisher	SUM battery backpack 1200v							UC banks & root wads	0	2	3	3
Cast net								Substrate	4	3	4	3
Seine net	-							Water column	4	4	3	3

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Labeobarbus marequensis	27	3	4	12	8	*Pseudocrenilabrus philander*	16		3		13
Chiloglanis pretoriae	4			4		*Enteromius unitaeniatus*	11			9	2
Enteromius trimaculatus	12			2	10	*Labeo molybdinus*	4	3		1	
Micropanchax johnstoni	1		1			*Enteromius viviparus*	11				11
Labeo cylindricus	22	5		17		*Engraulicypris brevianalis*	9			7	2
Enteromius radiatus	4			4		*Micralestes acutidens*	8			3	5
Oreochromis mossambicus	4		4								
						TOTAL ABUNDANCE:	133	11	12	59	51

The FRAI score was 90.7%, an **A/B** category, the main drivers of change being flow and water quality (**Table 8.13**).

Table 8.13: Site EWR 5: Summary of the results of the FRAI Ecostatus model.

Habitat metric	% deviation from natural	Overall % impact on fish assemblage
Velocity Depth classes	0.0%	5.24%
Cover	9.7%	14.5%
Flow modifications	35.0%	7.3%
Physico-chemical	35.4%	5.5%
Migrations		14.1%
Introduction of alien species	0.0%	0.0%
Introduced & translocated species	0.0%	0.0%
FRAI Score	90.7%	**A/B**

8.2.3.6 6_Kolope

6_Kolope was dry during the high and low flow season surveys (**Figure 8.7**) so no fish sampling was done. Historical data (Angliss 1998 in FBSIS database) recorded 12 fish species in April 1998 upstream of 6_Kolope; no abundances were indicated. The list included migratory and non-migratory fish and it is not known whether migratory fish are still able to move up the river past the newly installed sediment control structures. It is likely that the *Labeo* and *Chiloglanis* spp. recorded in the past no longer visit at high flows because of the lack of spawning gravels and riffles respectively. If anything, the river in its current state would probably only support tolerant fish. This is a poor site for fish.



Sediment control weir constructed from Gabions, an artificial migration barrier.



The dry riverbed showing the sandy channel bottom.

Figure 8.7: No fish habitat at 6_Kolope

8.2.3.7 7_Sand

7_Sand was dry during both the high and low flow surveys; there were no fish to sample (**Figure 8.8**). This river was sandy with little marginal vegetation but there were pools downstream where fish were known to take refuge in the dry season, waiting for the floods. Fish, if present, would utilise these pools to survive the dry season until flow was restored in the wet season. There were numerous instream barriers downstream to the Limpopo River with varying levels of passability. It is unlikely these difficult hydraulic conditions will be negotiated successfully by the migratory fish so recruitment events will be rare.



Downstream of the bridge there were gravel and cobble beds.



The riparian zone on the right bank with little marginal vegetation.

Figure 8.8: No fish habitat at 7_Sand

8.2.3.8 8_Nzhelele

8_Nzhelele comprised a pool, riffle/run, pool sequence at low flow, and there were side channels activated on both banks at high flow (**Figure 8.9)**. Gravel and sand were the main substrate on the left bank with boulders, bedrock and cobbles on the right bank. There was a high diversity of fish habitat; predominantly fast-shallow flow, some slow-shallow and slow-deep pools, and a few areas of fast deep flow. There was limited marginal vegetation with a few reeds and grasses touching the water at low flow. Surrounding land-use was game farming and conservancies so there were many natural features, with a few fallows, grazing areas still visible.



Runs and riffles with emergent boulders that provided hydraulic variability.



A large alluvial bar separated the main and side channel.



The side channel where juveniles took refuge.



A downstream view of the site.

Figure 8.9: Fish habitat at 8_Nzhelele

There were seven species and 120 fish caught with a cast net during the low flow survey, a good and speciose catch **Table 8.14**.

The cichlids *Oreochromis mossambicus* and *Coptodon rendalli* dominated the deeper slow-flowing areas, as expected, and there were fewer *Labeos* in the riffles.

Table 8.14: Fish and habitat data at 8_Nzhelele (low flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
-	X60			20 %	25 %	20 %	35 %	OH Veg	0	3	3	3
Equipment details (mesh size, etc):								Aq Veg	0	1	1	1
Electro-fisher	-							UC banks & root wads	0	3	3	3
Cast net	6ft, 20mm							Substrate	4	3	3	3
Seine net	-							Water column	4	4	2	2

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Labeobarbus marequensis	10			4	6	*Oreochromis mossambicus*	60		56		4
Pseudocrenilabrus philander	7		3	2	2	*Coptodon rendalli*	37		37		
Chiloglanis pretoriae	2			2		*Micropanchax johnstoni*	2		2		
Labeo cylindricus	2			2							
TOTAL ABUNDANCE:	120	-	98	10	12						

There was a bumper catch of 14 species and 258 fish during the high flow survey (**Table 8.15**) and some of these were juveniles taking refuge in the side channels, where there was good cover of overhanging plants. The fastest flowing sections was where larger *Labeobarbus marequensis* and *Labeo cylindricus* were caught, and the other riffles and runs supported four species of *Enteromius* and other smaller-bodied fish. There were many suitable breeding riffles along the river that were clear of sediment and debris.

Table 8.15: Fish and habitat data at 8_Nzhelele (high flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
120m in	-			5%	5%	65 %	25 %	OH Veg	1	3	3	4
Equipment details (mesh size, etc):								Aq Veg	1	2	3	3
Electro-fisher	SUM battery backpack 1200v							UC banks & root wads	1	3	3	3
Cast net	-							Substrate	3	2	4	4
Seine net	-							Water column	4	4	3	3

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Labeobarbus marequensis	52	27	3	16	6	*Engraulicypris brevianalis*	7			2	5
Chiloglanis pretoriae	39	5		34		*Micralestes acutidens*	3				3
Enteromius trimaculatus	22			16	17	*Oreochromis mossambicus*	12	1	10	1	
Clarias gariepinus	4		2	2		*Pseudocrenilabrus philander*	19		10		9
Labeo cylindricus	63	33		27	3	*Enteromius unitaeniatus*	8			8	
Enteromius radiatus	6			5	1	*Coptodon rendalli*	11		11		
Enteromius viviparus	11				11	*Micropanchax johnstoni*	1		1		
TOTAL ABUNDANCE:	258	66	37	111	55						

The FRAI score was 83.4%, a **B** category (Table 8.16) with flow and water quality modification scoring highest as drivers of change from natural, but there was a good match between the observed fish and those expected to occur.

Table 8.16: FRAI results at 8_Nzhelele

Habitat metric	% deviation from natural	Overall % impact on fish assemblage
Velocity Depth classes	5.6%	0.0%
Cover	9.7%	14.3%
Flow modifications	35.6%	28.4%
Physico-chemical	27.4%	26.3%
Migrations		14.1%
Introduction of alien species	0.0%	0.0%
Introduced & translocated species	0.0%	0.0%
FRAI Score	83.4%	**B**

8.2.3.9 9_Ṅwaneḍi

9_Ṅwaneḍi was a narrow river that was well-shaded beneath an enclosed canopy (**Figure 8.10**). There was a culvert under a bridge at the upper end of the site that flowed out into a plunge pool, downstream of which there was a riffle-run sequence over cobbles and gravels. There were marginal plants on the left bank that was more stable, and fewer on the alluvial sandbar of the right bank that was more active and where livestock were watered daily. There was some large woody debris and exposed plant roots that would be inundated during high flow, both good habitat for fish. Downstream there was some bedrock and the canopy had opened allowing more sunlight in. There was some garbage on the right bank because people visit the river to water their cattle and probably to wash clothes.



A riffle-run downstream of the culvert.



Overhanging vegetation, good cover from predators.



Exposed tree roots diverting flow to the left bank



A downstream view of the site.

Figure 8.10: Fish habitat at 9_Ṅwaneḍi

There were two species and five fish caught during the low flow survey with a cast net (**Table 8.17**). *Labeobarubs marequensis* and *Chiloglanis pretoriae* both require fast flowing water of relatively good quality.

Table 8.17: Fish and habitat data at 9_Ṅwaneḍi (low flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
-	X20			0%	25 %	5%	70 %	OH Veg	0	3	0	1
Equipment details (mesh size, etc):								Aq Veg	0	1	1	1
Electro-fisher								UC banks & root wads	0	3	0	1
Cast net	6ft, 20mm							Substrate	0	4	1	4
Seine net	-							Water column	3	4	1	2

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Labeobarbus marequensis	2			2							
Chiloglanis pretoriae	3			3							
TOTAL ABUNDANCE:	5	-	-	5	-						

A bumper catch of 12 species and 242 fish was made during the high flow survey (**Table 8.18),** which was surprising given the short length of the reach, the supposed disturbance from humans and livestock and the culvert migration barrier. Most of the fish were caught in the plunge pool immediately downstream of the culvert; especially *Labeo cylindricus, Labeo molybdinus* and *Labeobarbus marequensis*. These migratory fish may have reached their upper limit, or where on their way upstream if flows presented an opportunity to move pass the barrier.

Table 8.18: Fish and habitat data at 9_Ṅwaneḍi (high flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
100m in	-			5	10	65	20	OH Veg	1	3	2	4
Equipment details (mesh size, etc):								Aq Veg	0	1	1	3
Electro-fisher	SUM battery backpack 1200v							UC banks & root wads	2	3	3	3
Cast net	-							Substrate	1	4	4	4
Seine net	-							Water column	4	4	3	3

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Labeobarbus marequensis	27	16	3	7	1	*Enteromius viviparus*	57		2	52	3
Chiloglanis pretoriae	39			33	6	*Labeo molybdinus*	6	4		2	
Enteromius paludinosus	2				2	*Micralestes acutidens*	17		2	3	12
Clarias gariepinus	3			3		*Oreochromis mossambicus*	4		4		
Labeo cylindricus	32	22	3	6	1	*Pseudocrenilabrus philander*	7				7
Enteromius radiatus	9			6	3	*Enteromius unitaeniatus*	39	4		33	2
TOTAL ABUNDANCE:	242	46	14	143	37						

The FRAI score was 78.1%, a **B/C** category with flow and water quality modification scoring highest, followed by changes to flow-depth classes (**Table 8.19**).

Table 8.19: FRAI results for 9_Ṅwaneḍi

Habitat metric	% deviation from natural	Overall % impact on fish assemblage
Velocity Depth classes	18.7%	9.3%
Cover	9.5%	13.1%
Flow modifications	33.3%	34.1%
Physico-chemical	35.4%	38.8%
Migrations	0.0%	14.1%
Introduction of alien species	0.0%	0.0%
Introduced & translocated species	0.0%	0.0%
FRAI Score	78.1%	**B/C**

8.2.3.10 10_Latonyanda

10_Latonyanda flowed through a forest with a closed canopy of woody trees with shallow but vertical banks covered in marginal grasses and shrubs **(Figure 8.11**). There were repetitive riffle-run sequences

around boulders and over cobbles and gravel. There were slow-flowing areas with sand and mud and overhanging vegetation, with large woody debris. The water was turbid because of a high sediment load from the many dirt forest roads and cleared stands of cultivated trees.

There were nine species and 58 fish caught during the low flow survey **Table 8.20**, a good catch that matched the diversity of habitats. There was lots of cover for juveniles and the shallow cobble riffles was where *Amphilius uranoscopus, Chiloglanis pretoriae, Labeobarbus marequensis* and *Labeo cylindricus* were found, which all prefer fast flow. The quieter and deeper habitats were where the smaller *Enteromius* species were found.



A riffle-run.



Overhanging vegetation and large woody debris.



A pool-riffle.



Large cobbles in the riffles.

Figure 8.11: Fish habitat at 10_Latonyanda

Table 8.20: Fish and habitat data at 10_Latonyanda (low flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
85min	-			0%	20 %	75 %	5%	OH Veg	0	3	3	3
Equipment details (mesh size, etc):								Aq Veg	0	1	1	1
Electro-fisher	SAMUS 1000v backpack Electro-fisher							UC banks & root wads	0	3	3	2
Cast net	-							Substrate	0	4	5	5
Seine net	-							Water column	0	4	3	3

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Pseudocrenilabrus philander	5				5	*Enteromius neefi*	2			2	
Labeobarbus marequensis	6			4	2	*Enteromius viviparus*	4			4	
Enteromius afrohamiltoni	2				2	*Enteromius eutaenia*	11			11	
Amphilius uranoscopus	17			17		*Chiloglanis pretoriae*	4			4	
Labeo cylindricus	7			7							
TOTAL ABUNDANCE:	58	-	-	49	9						

There were 11 species and 98 fish captured during the high flow survey, more than in the colder dry flow period which was to be expected (**Table 8.21**). This was especially the case for migratory fish that overwintered downstream out of the closed canopy, where water temperatures would have been higher, and migrated back upstream for the summer to breed.

Table 8.21: Fish and habitat data at 10_Latonyanda (high flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
90min				0	10	55	35	OH Veg	0	3	4	4
Equipment details (mesh size, etc):								Aq Veg	0	2	1	1
Electro-fisher	SUM 1200v battery backpack Electro-fisher							UC banks & root wads	0	4	4	1
Cast net	-							Substrate	0	2	4	4
Seine net	-							Water column	0	4	2	2

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Labeobarbus marequensis	9		2	4	3	*Enteromius viviparus*	3			2	1
Chiloglanis pretoriae	28			26	2	*Enteromius bifrenatus*	2				2
Enteromius radiatus	6			2	4	*Enteromius trimaculatus*	6				6
Amphilius uranoscopus	4			4		*Coptodon rendalli*	1				1
Labeo cylindricus	13			9	4	*Enteromius unitaeniatus*	4			4	
Enteromius paludinosus	2				2						
TOTAL ABUNDANCE:	78	0	2	51	25						

The FRAI score was 77.3%, a **C** category **Table 8.22**. The highest driver was changes to water quality, then flow, but also there were moderate differences between the fish observed and expected.

Table 8.22: FRAI results for 10_Latonyanda

Habitat metric	% deviation from natural	Overall % impact on fish assemblage
Velocity Depth classes	0.0%	15.5%
Cover	0.9%	25.5%
Flow modifications	18.3%	24.7%
Physico-chemical	36.6%	27.6%
Migrations	-	20.0%
Introduction of alien species	0.0%	0.0%
Introduced & translocated species	0.0%	0.0%
FRAI Score	77.3%	**C**

8.2.3.11 11_Mutshindudi

11_Mutshindudi runs from a cascade into a large pool, then into a single fast-flowing channel with bedrock where Matumi (*Breonadia salicinia)* grows (**Figure 8.12**). The channel braids further downstream where there was a greater diversity of habitat with slower shallower areas over cobbles, gravel, and sand. There were bedrock mid-channel bars where *Breonadia salicinia* and *Combretum erythrophyllum* grew and recruited, which created intertwined roots that were inundated at low and high flow. Twisting inundated tree roots offered hydraulically sheltered areas where smaller fish could take refuge. Even further downstream, the braids came together into a fast-deep single channel with marginal reeds. This section of river was popular and visited every day by locals that watered their livestock, washed clothes, bathed and collected water. The fish habitat was diverse despite there being limited marginal vegetation.

There were five species and 52 fish caught during the low flow survey, fewer than expected considering the diverse and good quality habitat available (**Table 8.23**). Adults of the three migratory fish *Labeobarbus marequensis, Labeo molybdinus* and *Labeo cylindricus* were caught in the large pool at the base of the plunge pool and in the second pool, one level higher upstream of the plunge pool. These fish were migrating upstream.

There were 12 species and 57 fish caught during the high flow season (**Table 8.24**). A new species, not found at other sites, was *Opsaridium peringueyi*, which was sensitive to poor water quality. Overall, this site delivered the diversity and fish expected to occur based on the quality of the available habitat.



A rocky dyke intrusion on the right bank.



The main channel with bedrock on the right bank, shallow flow areas and fast-deep flow at the thalweg.



The cascade upstream.



The pool downstream of the cascade.

Figure 8.12: Fish habitat at 11_Mutshindudi

Table 8.23: Fish and habitat data at 11_Mutshindudi (low flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
95min				0%	5%	75 %	20 %	OH Veg	1	2	3	1
Equipment details (mesh size, etc):								Aq Veg	0	1	1	1
Electro-fisher	SAMUS 1000v backpack Electro-fisher							UC banks & root wads	1	2	2	1
Cast net	-							Substrate	1	4	5	5
Seine net	-							Water column	3	4	2	3

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Amphilius uranoscopus	10			8	2	*Labeobarbus marequensis*	9			9	
Labeo cylindricus	12			9	3	*Chiloglanis pretoriae*	19			19	
Labeo molybdinus	2			2							
TOTAL ABUNDANCE:	52	-	-	47	5						

The FRAI score was 67.7%, a **C** category (**Table 8.25**), with modifications scored for flow and water quality, and there being moderate differences between the observed and expected fish assemblage.

Table 8.24: Fish and habitat data at 11_Mutshindudi (high flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
90min	10x			0%	5%	60 %	35 %	OH Veg	1	2	4	3
Equipment details (mesh size, etc):								Aq Veg	0	1	1	1
Electro-fisher	SUM 1200v backpack Electro-fisher							UC banks & root wads	1	2	4	2
Cast net	6ft, 20mm							Substrate	1	3	4	4
Seine net	-							Water column	4	4	2	2

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Labeobarbus marequensis	7		2	4	1	*Enteromius trimaculatus*	6			2	4
Chiloglanis pretoriae	13			13		*Enteromius unitaeniatus*	4			3	1
Enteromius radiatus	3				3	*Opsaridium peringueyi*	1			1	
Amphilius uranoscopus	2			2		*Oreochromis mossambicus*	4		3		1
Labeo cylindricus	6	1		4	1	*Labeo molybdinus*	1	1			
Enteromius viviparus	8				8						
Enteromius bifrenatus	2				2						
TOTAL ABUNDANCE:	57	2	5	29	21						

Table 8.25: FRAI results for 11_Mutshindudi

Habitat metric	% deviation from natural	Overall % impact on fish assemblage
Velocity Depth classes	0.0%	29.5%
Cover	1.4%	46.9%
Flow modifications	36.1%	35.1%
Physico-chemical	32.2%	36.1%
Migrations	-	14.1%
Introduction of alien species	0.0%	0.0%
Introduced & translocated species	0.0%	0.0%
FRAI Score	67.7%	**C**

8.2.3.12 12_Luvuvhu

12_Luvuvhu was dominated by riffle-runs over cobbles, and slower flowing marginal areas over sand and gravel with dense reed beds. There were mid-channel bars with reeds and a side channel on the first terrace of the right bank that was dry during the low flow survey and inundated during the high flow survey, which offered a refuge (**Figure 8.13**). Washing of cars, bathing, watering of livestock and water collection took place at the site. Urban refuse had washed in from stormwater drains and over the road.

There were thirteen species and 61 fish caught during the low flow survey; good diversity at moderate abundance (**Table 8.26**). There were fewer fish caught during the high flow survey because much of the channel could not be fished, the flows were too high to access the river safely (**Table 8.27**). Overall there were more fish species caught than expected, based on the habitat conditions observed. Most of

the fish were caught in the shallower, slower flowing areas, but the *Labeo spp.* were out in the main channel. *Anguilla marmorata* was caught on the high flow survey, having migrated up the Limpopo and into the Luvuvhu River. This fish is renowned for crossing migratory barriers, using their bodies to wedge between cracks in rocks or concrete.



Fast-deep habitat of the main channel.



The side channel on the right bank at high flow.



The side channel on the right bank at low flow.



A hydraulically sheltered nursery area for juveniles.



Clear water and filamentous algae.



Marginal reeds.

Figure 8.13: Fish habitat at 12-Luvuvhu

The FRAI score was 70%, a **C** category **Table 8.28**. The ratings were influenced by the retention of good flows and apparent water quality. Ratings were effected by a relatively high difference between the fish observed and those that were expected from the reference list. The majority of the missing fish were intolerant of poor water quality.

Table 8.26: Fish and habitat data at 12_Luvuvhu low flow

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
90min				25	0	50	25	OH Veg	1	2	4	3
Equipment details (mesh size, etc):								Aq Veg	0	1	1	1
Electro-fisher	SUM battery backpack 1200v							UC banks & root wads	1	0	4	2
Cast net	-							Substrate	1	4	4	4
Seine net	-							Water column	4	4	2	2

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Labeobarbus marequensis	6	1		4	1	*Enteromius trimaculatus*	8				8
Chiloglanis pretoriae	6			6		*Pseudocrenilabrus philander*	4				4
Enteromius radiatus	3			1	2	*Enteromius annectens*	1				1
Clarias gariepinus	3			1	2	*Glossogobius callidus*	2			2	
Labeo cylindricus	17	3		12	2	*Oreochromis mossambicus*	2			1	1
Enteromius viviparus	4			2	2	*Labeo molybdinus*	1			1	
Tilapia sparrmanii	4				4						
TOTAL ABUNDANCE:	61	4	0	30	27						

Table 8.27: Fish and habitat data at 12_Luvuvhu high flow

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
90min				25 %	<1 %	50 %	25 %	OH Veg	2	2	2	2
Equipment details (mesh size, etc):								Aq Veg	0	1	1	1
Electro-fisher	SAMUS 1000v backpack Electro-fisher							UC banks & root wads	1	0	1	1
Cast net								Substrate	5	4	5	4
Seine net	-							Water column	4	4	4	3

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Anguilla marmorata	1			1		*Labeobarbus marequensis*	5			4	1
Labeo cylindricus	10	3		5	2	*Chiloglanis pretoriae*	16			16	
TOTAL ABUNDANCE:	32	3	-	26	3						

Table 8.28: FRAI results for 12_Luvuvhu

Habitat metric	% deviation from natural	Overall % impact on fish assemblage
Velocity Depth classes	7.0%	29.6%
Cover	4.8%	29.6%
Flow modifications	33.3%	35.0%
Physico-chemical	29.4%	41.8%
Migrations	-	14.1%
Introduction of alien species	0.0%	0.0%
Introduced & translocated species	0.0%	0.0%
FRAI Score	70.0%	**C**

8.2.3.13 13_Mutale1

13_Mutale1 comprised a fast flowing rapid of bedrock and boulders, with few gravels and fines along the sheltered marginal areas (**Figure 8.14**). The channel was braided with mid-channel bars with reeds and sedges. The main habitat was fast-deep flow over bedrock and boulders. Cobble and gravel were limited but the interstitial spaces were clean and where a large number of fish were caught. There were undercut banks on the channels edge that were refugia for small fish and juveniles, and the marginal vegetation was dense. There was a floodplain wetland on the left bank where groundwater was upwelling, and there were stagnant pools with aquatic plants.



The floodplain wetland with upwelling groundwater.



Fast-shallow and fast-deep flow over bedrock and boulders, and vegetated mid-channel bars.



Inundated marginal vegetation.



Overhanging vegetation and undercut banks.

Figure 8.14: Fish habitat at 13_Mutale1

There were seven species and 21 fish caught at low flow, moderate diversity and low abundance for a river that exhibits a good variety of habitat of good quality (**Table 8.29**). Nonetheless, the expected pattern of fish that prefer fast-flowing water, such as *Labeo* spp. and *Chiloglanis* spp. in the main channel, and fish that prefer slow-flowing water , such as *Enteromius* spp. and Cichlidae in the sheltered periphery, was evident.

Table 8.29: Fish and habitat data at 13_Mutale1 (low flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
95min	X15			10	<1	65	25	OH Veg	2	4	4	4
Equipment details (mesh size, etc):								Aq Veg	3	2	3	3
Electro-fisher	SAMUS 1000v backpack Electro-fisher							UC banks & root wads	3	3	3	3
Cast net	6ft, 20mm							Substrate	5	4	5	4
Seine net	-							Water column	4	4	4	3

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Labeo cylindricus	3			3		*Enteromius annectens*	2				2
Labeobarbus marequensis	3			2	1	*Enteromius trimaculatus*	5				5
Chiloglanis pretoriae	4			4		*Enteromius lineomaculatus*	2				2
Pseudocrenilabrus philander	2				2						
TOTAL ABUNDANCE:	21	-	-	9	12						

There were 14 species and 135 fish caught at high flow (**Table 8.30**), probably higher because more fish could have bypassed the natural migration barrier downstream at high flow. Two new species caught were the mormyrids *Marcusenius macrolepidotus* and *Petrocephalus wesselsi* and the gobiid *Glossogobius callidus*; these preferred the undercut banks and slow-flowing vegetated areas.

Table 8.30: Fish and habitat data at 13_Mutale1 (high flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
105min	10x			10	0	65	25	OH Veg	2	4	4	4
Equipment details (mesh size, etc):								Aq Veg	1	3	2	3
Electro-fisher	SUM battery backpack 1200v							UC banks & root wads	2	3	4	3
Cast net	6ft, 20mm							Substrate	4	4	4	4
Seine net	-							Water column	4	4	2	3

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Labeobarbus marequensis	11	2		8	1	*Enteromius trimaculatus*	27			20	7
Chiloglanis pretoriae	22	7		15		*Pseudocrenilabrus philander*	2				2
Marcusenius macrolepidotus	9		8		1	*Enteromius bifrenatus*	4				4
Petrocephalus wesselsi	16		14		2	*Glossogobius callidus*	3			3	
Labeo cylindricus	13	3		8	2	*Oreochromis mossambicus*	4		2	1	1
Enteromius viviparus	6				6	*Clarias gariepinus*	4				4
Tilapia sparrmanii	7		4		3	*Coptodon rendalli*	7		3	1	3
TOTAL ABUNDANCE:	135	12	31	56	36						

The FRAI score was 73.1%, a **C** category with low scores for habitat modification and higher scores for differences between the observed and expected fish assemblage (**Table 8.31**).

Table 8.31: FRAI results for 13_Mutale1

Habitat metric	% deviation from natural	Overall % impact on fish assemblage
Velocity Depth classes	0.0%	22.2%
Cover	0.0%	29.5%
Flow modifications	8.8%	32.4%
Physico-chemical	9.1%	29.6%
Migrations	-	14.1%
Introduction of alien species	0.0%	0.0%
Introduced & translocated species	0.0%	0.0%
FRAI Score	73.1%	**C**

8.2.3.14 14_Mutale2

14_Mutale2 was downstream of a gauging weir and comprised rapids and riffles interspersed with pools where there were crocodiles; these were not sampled (**Figure 8.15**). The fast-flowing area downstream of the weir moved over bedrock and there was a slow-flowing area on the left bank over bedrock and boulders with marginal vegetation on gravels and sands. There were many reeds on the channel margins and some of the large trees had root wads that would be inundated at high flow.

There were 11 species and 143 fish caught during the low flow survey **Table 8.32**.
There were adult migratory fish at the base of the weir, strong swimmers like *Labeo cylindricus, L. rosae, L. molybdinus* and *Labeobarbus marequensis* that would be able to pass the barrier at high flow. Other habitat specialists *Amphilius uranoscopus, Chiloglanis pretoriae, C. swierstrai*, and *C. paratus* were abundant.



Fast-deep flow downstream of the weir.



Slow-shallow flow where juveniles were found.



Boulders and bedrock in the main channel.



Gravels and sands at the edges.

Figure 8.15: Fish habitat at 14_Mutale2

Table 8.32: Fish and habitat data at 14_Mutale2 (low flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
100m in	X25			15	10	50	25	OH Veg	1	4	4	4
Equipment details (mesh size, etc):								Aq Veg	1	1	1	1
Electro-fisher	SAMUS 1000v battery backpack Electro-fisher							UC banks & root wads	2	3	3	3
Cast net	6ft, 20mm							Substrate	4	4	4	4
Seine net	-							Water column	4	4	3	3

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Labeo cylindricus	16	12		4		*Pseudocrenilabrus philander*	19		3		16
Labeo molybdinus	7	6		1		*Micralestes acutidens*	38		11		27
Labeobarbus marequensis	19	11		8		*Labeo rosae*	4	4			
Chiloglanis pretoriae	19			19		*Amphilius uranoscopus*	13			13	
Chiloglanis paratus	4			4		*Anguilla marmorata*	1			1	
Chiloglanis swierstrai	3			3							
TOTAL ABUNDANCE:	143	33	14	53	43						

There were nine species and 50 fish caught during the high flow survey (**Table 8.33**), with fewer migratory fish probably because many had already moved past the barrier. There still was a good diversity of species albeit at a lower abundance.

Table 8.33: Fish and habitat data at 14_Mutale2 (high flow)

Method & Effort (/meas unit):				% site sampled/ Vel-Depth class				Rating of Vel-Depth class per habitat type (0-5)				
El-F	C-Net	S-Ns	S-Nb	FD	SD	FS	SS	Hab type	FD	SD	FS	SS
100m in	10x			15	10	50	25	OH Veg	1	4	4	4
Equipment details (mesh size, etc):								Aq Veg	1	1	1	3
Electro-fisher	SUM 1200v battery backpack Electro-fisher							UC banks & root wads	2	3	3	3
Cast net	6ft, 20mm							Substrate	4	4	5	4
Seine net	-							Water column	4	4	4	3

Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS	Spp (& numbers per V-D class):	Tot	FD	SD	FS	SS
Labeobarbus marequensis	17	5		12		*Glossogobius callidus*	3			2	1
Chiloglanis pretoriae	4	1		3		*Coptodon rendalli*	2				2
Enteromius radiatus	2			2		*Labeo molybdinus*	1			1	
Enteromius lineomaculatus	9			2	7	*Micralestes acutidens*	8			2	6
Labeo cylindricus	4	1		3							
TOTAL ABUNDANCE:	50	7	0	27	16						

The FRAI score was 73.1%, a **C** category, with low scores given to habitat moderation and high scores given to differences in the observed catch relative to that expected (**Table 8.34**).

Table 8.34: FRAI results at 14_Mutale2

Habitat metric	% deviation from natural	Overall % impact on fish assemblage
Velocity Depth classes	24.5%	28.0%
Cover	0.0%	40.1%
Flow modifications	8.1%	34.7%
Physico-chemical	8.3%	44.7%
Migrations	-	14.1%
Introduction of alien species	0.0%	0.0%
Introduced & translocated species	0.0%	0.0%
FRAI Score	73.1%	**C**

8.3 Fish indicators

A list of fish indicators and the reasons for their selection is given in **Table 8.35**. The assemblages of fish observed at the EWR sites were grouped into four flow guilds.

Table 8.35: Fish indicators and their reason for selection

Indicator	Reason for selection	EWR site													
		1_Lephalala	2_Rietfontein	3_Olifantspruit	4_Mogalakwena1	5_Mogalakwena2	6_Kolope	7_Sand	8_Nzhelele	9_Ṅwaneḍi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale1	14_Mutale2
Rheophilic species	…inhabit cobble or rocky habitat in fast flowing water.														
Peripheral dwelling species	…inhabit quiet backwater areas with overhanging vegetation.														
Migratory fish	…undertake annual migrations to feed and breed, or complete a portion of their life cycle.														
Eurytopic species	…are tolerant to a range of flow and water quality conditions.														
Overall fish health	A composite measure of fish integrity.														
Species diversity	A robust measure of biodiversity.														

8.3.1 Rheophilic fish

Life history characteristics of rheophilic (inhabitating flowing water habitats) summarised in **Table 8.36**. The indicator selected for this guild was *Chiloglanis pretoriae*, the shortspine suckermouth (**Figure 8.16**). Linked indicators and their relationship with rheophilic fish are summarised in Table 8.37.



Figure 8.16: *Chiloglanis pretoriae* (Photograph: R Palmer)

Table 8.36: Life history characteristics for rheophilic fish

Niche/Indicator	Rheophilic fish
Key features	Species that prefer fast-flowing water. They have morphological adaptations (such as sucking mouth parts or modified fins) to attach to, and move along, rocks or bedrock in high flow. They are strong swimmers and dorso-ventrally flattened to be more streamlined in the face of strong flow.
Indicator species	*Chiloglanis pretoriae* Van der Horst, 1931 (Shortspine suckermouth) Mochokidae
Habitat	Riffle specialists, usually found in fast-flowing rapids and riffles. Substrates include bedrock, boulders, cobble and gravel with clean interstitial spaces.
Food	Aquatic insects such as mayfly nymphs, caddis fly and blackfly larvae (Skelton 2001).
Breeding	Summer, laying eggs amongst rocks and gravel in flowing water (Skelton 2001).
Key requirements	Well oxygenated, fast-flowing water of shallow to medium depth. Intolerant to poor water quality. Tend to be rare where there are algae or where fines are in excess.

Table 8.37: Linked indicators and their relationship with rheophilic fish

Linked indicator	Reasons	Relationship
Dry duration (Dry season)	A longer dry season limits the extent of fast flowing habitat for rocky riffle fish.	A longer dry season = fewer rheophilic fish.
Wet duration (Flood season)	Rheophilic fish are serial spawners, so a longer wet season provides more time to breed.	A longer wet season = more rheophilic fish.
Zero days per year (Dry season)	Zero flow days means no fast flow for rheophilic fish.	More zero flow days = fewer rheophilic fish.
Dry ave depth	Rheophilic fish prefer water depths of 300-750 mm (Skelton 2001).	Deeper water = more rheophilic fish.
Wet ave depth		
Embeddedness (All seasons)	Rheophilic fish inhabit the interstitial spaces between the cobbles and boulders to actively seek prey, for suitable spawning beds and to seek refuge from high turbulence and predators.	More embeddedness = fewer rheophilic fish.
Inundated cobble habitat (All seasons)	Inundated cobble is the preferred habitat of rheophilic fish.	More inundated cobble = more rheophilic fish.
Dissolved oxygen (All seasons)	Rheophilic fish like highly oxygenated water (de Villiers 1991).	Higher oxygen content = more rheophilic fish.
Algal biofilm (All seasons)	More biofilm means more invertebrates as food for rheophilic fish.	More biofilm = more rheophilic fish.
Comp: Invertebrate food for fish (All seasons)	Rheophilic fish eat invertebrates.	More invertebrates = more rheophilic fish.

8.3.2 Non-rheophilic fish

Life history characteristics of non-rheophilic fish (species that prefer quieter peripheral habitats away from the main channel) are summarised in **Table 8.38**. The indicator selected for this guild was *Enteromius trimaculatus*, the threespot barb (**Figure 8.17**). Linked indicators and their relationship with non-rheophilic fish are summarised in **Table 8.39**.

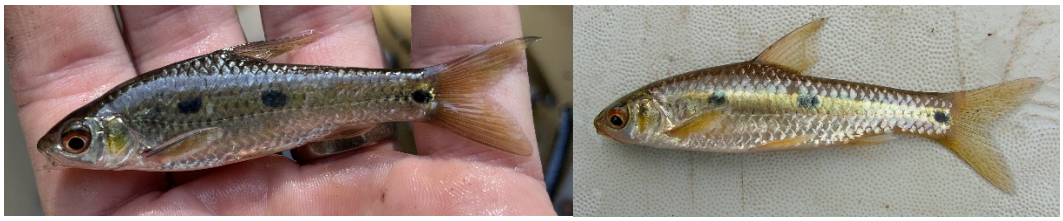


Figure 8.17: *Enteromius trimaculatus* (Photographs: Mathew Ross)

Table 8.38: Life history characteristics for non-rheophilic fish

Niche/Indicator	Quiet vegetated water fish
Key features	Fish that prefer and inhabit quiet vegetated waters on the edges of the river or in backwaters, away from the main channel.
Indicator species	*Enteromius trimaculatus* Peters, 1852 (Threespot barb) Cyprinidae
Habitat	It is a hardy species that commonly occurs in a wide variety of habitats, especially where there is vegetation (Skelton 2001).
Food	Feeds on insects and other small organisms (Skelton 2001).
Breeding	Breeds in summer, shoals of ripe adults move upstream after rain. Females produce as many as 8000 eggs (Skelton 2001).
Key requirements	Hydraulically sheltered zones away from the main current where marginal, aquatic, and emergent vegetation grow. Marginal graminoids on inset benches that are inundated during the wet season are important breeding habitat.

Table 8.39: Linked indicators and their relationship with non-rheophilic fish

Linked indicator	Reasons	Relationship
Dry duration (Dry season)	There are fewer quiet vegetated waters at the channels edge in the dry season where three-spot barb are found.	A longer dry season = fewer three-spot barbs.
Wet duration (Flood season)	There are more vegetated channel edge, inset and flood bench habitats in the wet season where three-spot barb are found.	A longer wet season = more three-spot barb.
Zero days per year (Dry season)	Fish and invertebrates are concentrated in standing pools on zero flow days, which increases competition for resources.	More zero flow days = fewer three-spot barb.
Wet: Ave (of ave) velocity (Flood season)	Three-spot barb like slow flowing water (i.e., non-rheophilic).	Higher velocity = less habitat = fewer three-spot barb.
Backwaters and Secondary channels (All seasons)	Three-spot barb inhabit backwaters and secondary channels.	More backwaters and secondary channels = more three-spot barb.
Inset bench and sand bars (Flood season)	Three-spot barb breed in marginal vegetation on inset benches and bars.	More inset benches and bars = more three-spot barb.
Flood bench (Flood season)	Three-spot barb breed in marginal vegetation on flood benches.	More flood benches = more three-spot barb.
Biocides (All seasons)	Biocides are poisonous to three-spot barb.	More biocides = fewer three-spot barb.
Aquatic vegetation (All seasons)	Three-spot barb breed in aquatic vegetation.	More aquatic vegetation = more three-spot barb.
Marginal zone graminoids (Flood season)	Three-spot barb breed in marginal zone graminoids.	More marginal zone graminoids = more three-spot barb.
Flood bench graminoids (Flood season)	Three-spot barb breed in flood bench graminoids.	More flood bench graminoids = more three-spot barb.
Comp: Invertebrate food for fish (All seasons)	Three-spot barb eat invertebrates.	More invertebrates = more three-spot barb.

8.3.3 Migratory fish

Life history characteristics of migratory fish are summarised in **Table 8.40**. The indicator selected for this guild was *Labeobarbus marequensis*, the largescale yellowfish (**Figure 8.18**). The linked indicators and their relationship with migratory fish are summarised in **Table 8.41**.



Figure 8.18: *Labeobarbus marequensis* (Photograph: Mathew Ross)

Table 8.40: Life history characteristics for migratory fish

Niche/Indicator	Migratory species
Key features	Fish that undertake annual migrations upstream or onto floodplains for breeding and feeding, or to complete a portion of their life cycles.
Indicator species	Examples are *Labeobarbus marequensis* and *Labeo cylindricus* (Cyprinidae) that are both cosmopolitan species found at >90% of sites. Migratory requirements are similar for both species.
Habitat	Migratory fish follow the current as they make their way upstream. Maintenance of flow is therefore important during the peak migratory period. Substrate and hydraulic variability are also important. Cobbles and boulders with low embeddedness provide interstitial spaces and hydraulic variability that fish use to their advantage to maintain position in high-velocity water.
Food	Aquatic invertebrates are a key food source for reproductive priming (gonadosomal development) in fish that are to undertake spawning migrations.
Breeding	Fish migrate in spring and summer to spawn on cobble and gravel beds in riffles and rapids, or in floodplain vegetation (Skelton 2001).
Key requirements	Timing of the onset of the wet season is a key trigger for migration. Connectivity and passage over instream barriers is important. If the fish are ready to spawn and have not reached suitable habitat, they are forced to spawn in unsuitable areas, often leading to a failed breeding season. Water quality is also key; an increase in water temperature is a trigger for reproduction and high oxygen levels boost fish health.

Table 8.41: Linked indicators and their relationship with migratory fish

Linked indicator	Reasons	Relationship
Dry duration (D season)	A longer dry season reduces the time for migrations and lowers breeding success.	A longer dry season = fewer migratory fish.
Wet onset (T1 season)	Delayed onset of the wet season delays migrations and spawning. An earlier onset is advantageous.	Later onset = fewer migratory fish.
Wet duration (F season)	A longer wet season provides greater opportunity for migration of adults upstream and juveniles downstream.	A longer wet season = more migratory fish.
Wet average daily volume (F season)	Higher volumes in the wet season promote downstream migrations of adults and juvenile fish. Lower volumes limit dispersal.	Higher daily volume = more migratory fish.

Linked indicator	Reasons	Relationship
Wet min (of average) depth (T1 season)	Migratory fish are large (450 mm TL) so need a minimum depth of water to successfully migrate.	Deeper water = more migratory fish.
Wet average (of average) depth (F season)	A suitable wet average depth promotes spawning activity and maintains spawning habitat. If the water column is too shallow, then the eggs and larvae/fry are too exposed (radiation, predation (mostly from wading birds), and water that is too shallow is too turbulent for eggs and larvae to maintain position.	Suitable water depth = more migratory fish.
Wet average (of average) velocity (T1 season)	Water velocity that is too slow does not trigger migration in the T1 season and does not maintain substrate cleanliness and oxygen levels to support proper egg development.	Optimal water velocity = more migratory fish.
Embeddedness (T1 season)	Lower degrees of embeddedness mean more clean interstitial spaces, more hydraulic variability and hiding areas for fish.	Lower embeddedness = more migratory fish.
Inundated cobble habitat (T1 season)	Inundated cobbles promote variability that support migratory fish.	More inundated cobble = more migratory fish.
Composite invertebrate food for fish (T1 season)	Migratory fish eat invertebrates.	More invertebrates = more migratory fish.

8.3.4 Tolerant (eurytopic) fish

Life history characteristics of tolerant fish are summarised in Table 8.42**.** The indicator selected for this guild was *Oreochromis mossambicus*, the Mozambique tilapia (**Table 8.18**).
Linked indicators and their relationship with tolerant fish are summarised in **Table 8.43**.



Figure 8.19: *Oreochromis mossambicus* adult male (left, Skelton (2001), juvenile (right, Photograph: Mathew Ross)

Table 8.42: Life history characteristics for tolerant fish

Niche/Indicator	Tolerant species
Key features	Fish that are tolerant to a range of flow and water quality conditions and are adaptable to fluctuations of environmental conditions. These species do not migrate, are omnivorous eating a wide range of food and thrive at low or slow flow and especially in dams. They tolerate high salinity, a wide range of temperature and low oxygen by breathing from the surface (Skelton 2001).
Indicator species	*Oreochromis mossambicus* Cichlidae (Mozambique tilapia)
Habitat	Wide tolerance from medium-fast water velocities through to zero flows. Tends to dominant in dams (Skelton 2001).
Food	Eats insects when young and more detritus, phytoplankton and algae when older (Skelton 2001).
Breeding	Breeds throughout the year. The male builds a nest and the female broods the eggs on the nest and in her mouth. As the eggs and fry are actively cared for hatching success and survival is high
Key requirements	Prefers quieter water with vegetation cover, especially when young, and thrives in dams.

Table 8.43: Linked indicators and their relationship with tolerant fish

Linked indicator	Reasons	Relationship
Dry duration (D season)	Sensitive fish struggle more in the dry season than tolerant fish, giving tolerant fish a competitive edge.	A longer dry season = more tolerant fish.
Wet duration (F season)	Tolerant fish benefit from a long wet season just to a lesser extent than sensitive fish.	A longer wet season = more tolerant fish.
Zero days per year (D season)	Tolerant fish thrive in stagnant water outcompeting sensitive fish.	More zero flow days = more tolerant fish, up to a point beyond which there will be fewer tolerant fish.
Embeddedness (All seasons)	Tolerant fish feed on animal and plants in cobbles.	More embeddedness = fewer tolerant fish.
Pool depth (All seasons)	Tolerant fish dominate in deep pools.	More pool depth = more tolerant fish.
Backwaters and secondary channels (All seasons)	Tolerant fish dominate in backwaters and secondary channels.	More backwaters and secondary channels = more tolerant fish.
Composite invertebrate food for fish (T1 season)	Tolerant fish eat invertebrates.	More invertebrates = more tolerant fish.

8.3.5 Fish health

Linked indicators and their relationship with fish health are summarised in **Table 8.44**.



Figure 8.20: Black spot caused by Trematode cysts (Photograph: Mathew Ross)



Figure 8.21: Ulcer-forming bacterial infections (Photograph: Mathew Ross)

Table 8.44: Linked indicators and their relationship with fish health

Linked indicator	Reasons	Relationship
Dry duration (D season)	The dry season is a stressor on a river system in general.	A longer dry season = lower fish health.
Zero days per year (D season)	More zero flow days increases competition for resources in isolated pools, increases the concentration of wastes and toxins, increases susceptibility to predation, increases temperature variability of the pool and impacts on oxygen availability.	More zero flow days = lower fish health.
Embeddedness (All seasons)	Exposed and clean substrates promote a healthy aquatic ecosystem and therefore promotes overall fish health due to a balance of habitat quality and resource availability (it also increases invertebrate activity and therefore food for fish).	More embeddedness = lower fish health.
Algal biofilms (All seasons)	Fish eat algal biofilms.	More algal biofilms = better fish health.
Comp: Invertebrate food for fish (All seasons)	Fish eat invertebrates.	More invertebrates = better fish health.

8.3.6 Species diversity

Linked indicators and their relationship with species diversity are summarised in **Table 8.45**.

Table 8.45: Linked indicators and their relationship with species diversity

Linked indicator	Reasons	Relationship
Dry duration (D season)	The dry season is a stressor on a river system in general.	A longer dry season = lower species diversity.
Wet onset	Onset of the wet season controls fish migration, and breeding cycles.	Earlier onset and delayed onset both = lower species diversity.
Wet duration (F season)	Fish interact with the inundated marginal plants in the wet season. The longer the duration of the wet duration, the more productive the population of these fish will be.	A longer wet season = higher species diversity.
Wet season volume (F season)	Fish move around during the wet season which promotes dispersal and reduces competition for resources.	Higher wet season volumes = higher species diversity.
Zero flow days per year (D season)	Flow within a river brings with it nutrients, oxygen and other resources. It improves water quality through the flushing of accumulated wastes and toxins. Flows also allow for dispersal and lowering of competition for resources within the riverine environment.	More zero flow days = more competition = lower species diversity.
Embeddedness (All seasons)	Exposed and clean substrates promote a healthy aquatic ecosystem and therefore promote overall fish.	More embeddedness = lower species diversity.
Inundated cobble habitat (All seasons)	Inundated cobbles are good habitat for fish and invertebrates.	More inundated cobbles = higher species diversity.
Algal biofilms (All seasons)	Fish eat algal biofilms.	More algal biofilms = higher species diversity.
Composite Invertebrate food for fish (All seasons)	Fish eat invertebrates.	More invertebrates = higher species diversity.

8.4 Status and trends

From a fish perspective, the basic assumptions associated with each time period were:

- 1900: preceding urban development and any significant instream infrastructure.
    - The land-use would have been natural with dense vegetation and some grazing by cattle.
    - Cultivation was limited and concentrated near rivers and wetlands.
    - Dirt roads were few and river crossings were low level and flooded frequently.
    - Instream infrastructure as barriers was limited to water abstraction structures that did not span the river, and some weirs to create deeper pools.
- 1960 was a period of government-sponsored agricultural development of irrigation schemes, crop production, animal husbandry, and dam and gauging weir building, as water use increased.
    - There was more clearing of natural land for cultivated fields, and a dramatic increase in sediment transported into rivers. Erosion management within this era would have been limited.

  - Urbanisation increased along with population in support of the mining, and agricultural sectors, as well as the commercial and industrial sectors, bringing industrial and mining, sewage and agrochemical pollution.
  - The development of instream infrastructure was undertaken with little regard for the maintenance of ecological integrity, so most formal bridges, culvert drains, pump stations, etc., lead to habitat fragmentation.
  - Development and the transformation of riparian zones was also unregulated, which meant an increase in erosion of the banks of the watercourses.
- 2000. Progressive legislature that supported the conservation of the overall ecological integrity of aquatic ecosystems, including its ecological drivers, contributed to spatial and development planning. Catchment-based management strategies were implemented with increasing legislative support, which meant that mitigation strategies and conservation-based decisions gained traction.
  - Although catchment management strategies were implemented and activities associated with surface water ecosystems became more stringently regulated, an overall increase in population within the urban areas placed increasing pressure on aquatic habitats.
  - Stormwater management in the urban environment saw many urban watercourses being canalised and regulated.
  - An increasing need for water as a resource also meant that stricter control over water volumes needed to be implemented, which saw a relatively high number of instream gauging structures being established. Gauging structures emerged as a significant cause of habitat fragmentation.

Figure 8.22 shows the general trends in the fish indicators. Migratory fish decreased from 1900 to 1960 as more and more in-channel structures were built, and thereafter was a steady decline in response to the cumulative impacts of instream barriers. Similarly, rheophilic fish declined because of the inundation of riffles by gauging and abstraction weirs and dams. Fish diversity and health would have followed these trends as basin-wide pressures and drivers of ecological change increased. Conversely, tolerant fish were expected to have increased in response to increasingly adverse conditions, to a point, beyond which they too will succumb. Quiet vegetated water fish remained stable as dams created habitat for the growth of aquatic and marginal vegetation.

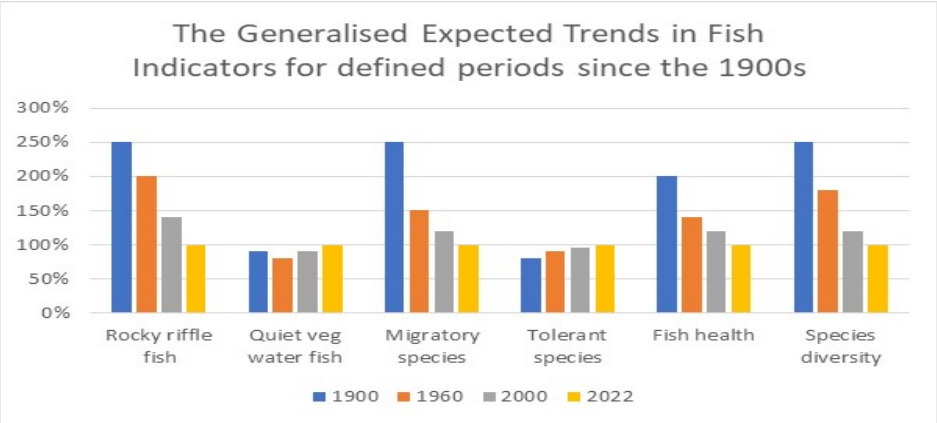


Figure 8.22: A generalised expected status and trends indication of the changes to population abundance of the fish indicators

8.4.1 Rheophilic fish

Relevant at all sites except 2_Rietfontein.

The main anthropogenic drivers of indicator status were:

- The construction of weirs and dams that inundated rocky riffles.
- Increased erosion in the basin bring in sediments that within the catchment area will lead to increased sediment deposition in the channel and higher levels of embeddedness of rocky riffle habitat.
- Abstraction of river water that reduces flow and depth of rocky riffles.
- Urban development that has changed flow patterns, with increased flood peaks as an example, and altered river channel structure through water resource developments and flood control structures.

Assuming the 2022 quantity of rocky riffle dependent fish was 100%, the estimated quantity in:

- *c.* 1900 was:
    - 350% at 1_Lephalala: An estimated 350% due to very limited instream infrastructure development and land-use change.
    - 250% at 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 7_Sand, 8_Nzhelele, 9_Ṅwaneḍi, 11_Mutshindudi and 12_Luvuvhu due to limited instream infrastructure and land-use change. Rheophilic fish populations would have been strongly driven by seasonality, with an influx of breeding adults during the summer breeding season in search of suitable upstream spawning habitat.
    - 150% at 10_Latonyanda, 13_Mutale1 and 14_Mutale2 for similar reasons but there being fewer differences between 1900 and PES (2022), where there was limited water resource development.
- *c.* 1960 was:
    - 200% at 1_Lephalala, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 7_Sand, 9_Ṅwaneḍi, 11_Mutshindudi and 12_Luvuvhu due to an increase in instream infrastructure that would impound water and inundate riffles, and a decrease in natural land-use and therefore increased erosion and embeddedness.
    - 180% at 8_Nzhelele after the Nzhelele Dam was established in 1948 that inundated riffles and created an instream barrier.
    - 120% at 10_Latonyanda, 13_Mutale1 and 14_Mutale2 due to increased afforestation and increased sediment loads that smother riffles at 10_Latonyanda, and limited instream infrastructure development on the Mutale River.
- *c.* 2000 was:
    - 110% at 1_Lephalala due to an increase of instream barriers.
    - 140% at 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 7_Sand, 8_Nzhelele, 9_Ṅwaneḍi, 11_Mutshindudi and 12_Luvuvhu due to cumulative impacts of instream barriers to accommodate land use development, leading to the increased inundation of rocky riffle habitat and the displacement of these fish.
    - 110% at 10_Latonyanda, 13_Mutale1 and 14_Mutale2 as there were no large differences between conditions at this time and PES (2022).

8.4.2 Non-rheophilic fish

Relevant at all EWR sites except 2_Rietfontein, 6_Kolope and 7_Sand.

The main anthropogenic drivers of indicator status were:

- Erosion of riverbanks due to poor catchment management.
- Constriction of the wetted perimeter because of increased abstraction that reduces inundation of marginal vegetation where these fish breeding and that juveniles use as nursery habitat.
- The construction of weirs and in-channel dams where aquatic and marginal vegetation grow, but these barriers would eventually lead to a decline of these species at the regional level.
- Urban development that increases flash floods that wash these fish downstream.

Assuming the 2022 quantity of quiet vegetated water fish was 100%, the estimated quantity in:

- *c.* 1900s was:
    - 250% at 1_Lephalala because there were fewer instream barriers downstream and the drought of 1980s had not decimated the population.
    - 60% at 3_Olifantspruit because this was an oligotrophic mountain stream where marginal vegetation was rare before afforestation and artificial sources of nutrients to the system promoted instream vegetation.
    - 90% at 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 9_Ṅwaneḓi, 10_Latonyanda and 11_Mutshindudi due to lower levels of nutrients from the more natural landscape.
    - 120% at 12_Luvuvhu, 13_Mutale1 and 14_Mutale2 because the physical characteristics of the river in the 1900s would have been very similar to PES (2022).
- *c.* 1960s was:
    - 120% at 1_Lephalala due to an increase in the number of instream barriers that prevent upstream migration after floods.
    - 95% at 3_Olifantspruit, 4_Mogalakwena1 and 5_Mogalakwena2 because of dams and weirs that impound water where aquatic and marginal plants grow.
    - 110% at 8_Nzhelele, 9_Ṅwaneḓi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2 because of dams and weirs that impound water where aquatic and marginal plants grow, and an increase in sediment transport to the rivers creates more alluvial habitat where marginal plants grow.
- *c.* 2000s was:
    - 105% at 1_Lephalala because of cumulative impacts of instream barriers and the loss of fish during the drought in the 1980s.
    - 95% at 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 9_Ṅwaneḓi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2 as conditions are near PES (2022).

8.4.3 Migratory fish

Relevant at all EWR sites except 2_Rietfontein.

The main anthropogenic drivers of indicator status were:

- The construction of instream impoundments, which fragments continuity and creates barriers to migration, which reduces breeding potential and isolates fish populations creating genetic bottlenecks.
- Changes in flow because of abstraction and flow regulation below.

Assuming the 2022 quantity of migratory fish was 100%, the estimated quantity in:

- *c.* 1900s was:
    - 350% at 1_Lephalala because of fewer instream structures as barriers
    - 250% at 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2 because of no instream barriers to migration.
    - 400% at 6_Kolope because of no instream barriers to migration.
    - 150% at 7_Sand because of no instream barriers to migration.
- *c.* 1960s was:
    - 250% at 1_Lephalala because of an increase in the number of instream barriers means that a decline in fish abundance would have started to take effect, but overall species diversity was still high.
    - 150% at 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2 because of the cumulative impacts of instream barriers and several large dams having been commissioned; Glen Alpine Dam on the Mogalakwena River, and the Nzhelele Dam on the Nzhelele River.
    - 300% at 6_Kolope because of an increase in instream barriers.
    - 135% at 7_Sand because of an increase in instream barriers.
    - *c.* 2000s was:
    - 100% at 1_Lephalala and 6_Kolope, same conditions as PES (2022).
    - 120% at 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 7_Sand, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2: An estimated 120% because of the cumulative impact of an increased number of instream structures and migratory barriers.

8.4.4 Tolerant (eurytopic) fish

Relevant at all EWR sites.

The main anthropogenic drivers of indicator status were:

- The construction of instream dams and weirs where tolerant fish dominate.
- Changes in land-use that drives changes in the flow of water, sediments and nutrients.

Assuming the 2022 quantity of tolerant fish was 100%, the estimated quantity in:

- *c.* 1900s was:
    - 80% at 1_Lephalala, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2 because of fewer human pressure and drivers of ecological change.
    - 60% at 2_Rietfontein because of fewer human pressure and drivers of ecological change.

- 90% at 7_Sand because of fewer human pressure and drivers of ecological change
- *c.* 1960s was:
- 90% at 1_Lephalala, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 7_Sand, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2 because of an increase in human pressure and drivers of ecological change.
- 110% at 2_Rietfontein because of an increase in human pressure and drivers of ecological change.
- *c.* 2000s was:
- 95% at 1_Lephalala, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 7_Sand, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2 because of an increase in human pressure and drivers of ecological change.
- 100% at 2_Rietfontein, same as PES (2022).

8.4.5 Fish health

Relevant at all EWR sites.

The main anthropogenic drivers of indicator status were:

- The cumulative impacts that result from an increase in human population within the catchment area and the subsequent use of the resources that leads to an increase in the pressures and drivers of ecological change. These include an increase in contaminants entering the system, changes to water quality, transformation of the geomorphological processes, and the subsequent influence on aquatic biota.
- Hydrological changes during low flow, for example increased duration of the dry season, when chemical pollutants are concentrated.

Assuming the 2022 level of overall fish health was 100%, the estimated quantity in:

- *c.* 1900s was:
  - 200% at 1_Lephalala, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 7_Sand, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2 because there were more natural landscapes, overall lack of substantial infrastructure development, and generally low human population.
  - 100% at 2_Rietfontein, same as PES (2022).
- *c.* 1960s was:
  - 140% at 1_Lephalala, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 7_Sand, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2 due to a decline in water quality because of the development of instream infrastructure, increased water abstraction, and changes in land-use.
  - 120% at 2_Rietspruit and 6_Kolope due to a decline in water quality because of the development of instream infrastructure, increased water abstraction, and changes in land-use.
- c. 2000s was:

- 120% at 1_Lephalala, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 6_Kolope, 7_Sand, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi, 12_Luvuvhu, 13_Mutale1 and 14_Mutale2 due to further changes in land-use.
- 100% at 2_Rietfontein, same as PES (2022).

8.4.6 Species diversity

Relevant at all EWR sites except 2_Rietfontein.

The main anthropogenic drivers of indicator status were:

- The construction of instream impoundments where tolerant fish dominate.
- Flow regulation that reduces hydrological variability.
- Water quality degradation of water quality.
- Degradation of aquatic habitat and ecological integrity.
- Longitudinal habitat fragmentation because of instream barriers.

Assuming the 2022 level of overall fish species diversity was 100%, the estimated quantity in:

- *c.* 1900s was:
  - 250% at all sites because of more natural landscapes, less flow regulation and less human use.
- *c.* 1960s was:
  - 200% at 1_Lephalala and 12_Luvuvhu are of the larger rivers and the first to have been developed and also have a greater buffer, being larger, against cumulative impacts that change water quality.
  - 190% at, 2_Rietfontein, 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi, 13_Mutale1 and 14_Mutale2 because of cumulative impacts associated with habitat fragmentation, together with incremental increases of catchment-based stressors would see a general decline in species diversity.
  - 160% at 6_Kolope and 170% at 7_Sand because of cumulative impacts associated with habitat fragmentation, together with incremental increases of catchment-based stressors would see a general decline in species diversity.
- *c.* 2000s was:
  - 110% at 1_Lephalala and 2_Rietfontein, 120% at 3_Olifantspruit, 4_Mogalakwena1, 5_Mogalakwena2, 7_Sand, 8_Nzhelele, 9_Ṅwaneḍi, 10_Latonyanda, 11_Mutshindudi, 13_Mutale1 and 14_Mutale2 because of cumulative impacts associated with habitat fragmentation, together with incremental increases of catchment-based stressors would see a general decline in species diversity.
  - 100% at 6_Kolope, same as PES (2022).

8.4.7 Summary of the status and trends per site.

The trends for all indicators at all sites are summarised in **Table 8.46**.

Table 8.46: Summary of trends for all fish indicators at all EWR sites

Indicator	Year	1_Lephalala	2_Rietfontein	3_Olifantspruit	4_Mogalakwena1	5_Mogalakwena2	6_Kolope	7_Sand	8_Nzhelele	9_Ṅwaneḍi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale1	14_Mutale2
Rheophilic fish	1900	350		250	250	250	250	250	250	250	150	250	250	150	150
	1960	200		200	200	200	200	200	180	200	120	200	200	120	120
	2000	110		140	140	140	140	140	140	140	110	140	140	110	110
Non-rheophilic water fish	1900	250		60	90	90			90	90	90	90	120	120	120
	1960	120		95	95	95			110	110	110	110	110	110	110
	2000	105		95	95	95			95	95	95	95	95	95	95
Migratory fish	1900	350		250	250	250	400	150	250	250	250	250	250	250	250
	1960	250		150	150	150	300	135	150	150	150	150	150	150	150
	2000	100		120	120	120	120	120	120	120	120	120	120	120	120
Eurytopic fish	1900	80	60	80	80	80	80	90	80	80	80	80	80	80	80
	1960	90	110	90	90	90	90	90	90	90	90	90	90	90	90
	2000	95	100	95	95	95	95	95	95	95	95	95	95	95	95
Fish health	1900	200	100	200	200	200	200	200	200	200	200	200	200	200	200
	1960	140	120	140	140	140	120	140	140	140	140	140	140	140	140
	2000	120	100	120	120	120	120	120	120	120	120	120	120	120	120
Species diversity	1900	250	250	250	250	250	250	250	250	250	250	250	250	250	250
	1960	200	190	190	190	190	160	170	190	190	190	190	200	190	190
	2000	110	110	120	120	120	100	120	120	120	120	120	120	120	120

8.5 Ecospecifications, TPCs and recommendations for monitoring

The EcoSpecs were calculated from the EcoStatus FRAI model. The tables provide an indication of the fish expected to occur at each EWR site and their abundance, representing a complete reference list of species that has been developed following multiple surveys over an extended period incorporating multiple seasons. Not all these fish are expected to occur at all times of the year nor to be caught on each sampling event. Because of this, there are limited species that could be singled out as indicators to be used when assigning EcoSpecs for each site. The expectation of sampling all the fish species that appear on the species reference list for each site is therefore unrealistic. Due to the variables outlined above, the absence of certain fish species (especially the less common species) should therefore not necessarily be interpreted as an indication of deteriorarion of the ecological integrity of a river reach unless long-term data indicates a trend.

Each of the survey sites included species that could be considered as flagship and indicative of an ecologically functional system. These species were chosen based on criteria such as habitat specificity and general occurrence within the catchment area. The evaluation of each survey site is based on the habitat type associated with each site and the expected target species that are specific to that habitat type. Species that were observed to be relatively common at each site and which showed habitat specificity (i.e., habitat niche species) were chosen and their presence or absence as well as their relative abundance at the site formed the basis of one of the EcoSpec categories for the site. These fish included rheophilic species (those fish that inhabit flowing habitat zones), non-rheophilic species (those fish that prefer quieter water, but which are regarded as sensitive to changes in ecological condition), and eurytopic species (fish that do not show a strong preference for a particular habitat type and are therefore highly adaptable to changing ecological conditions). These two categories are designated rankings of 1, 2 and 3, respectively in the tables below (where applicable). The relative abundance of

these species also is defined as part of the EcoSpecs for each site. A balanced species relative abundance defined by the habitat diversity available at each site would represent limited cause for concern, whereas a dominance of eurytopic species, regardless of habitat availability at the site, would be cause for concern (i.e., a TPC). Another EcoSpec category is that of the occurrence of alien fish species at a site. This is defined as the presence or absence of alien fish at each site, with the TPC defined as an overall percentage of the total number of fish surveyed at the site. The catch per unit effort (CPUE) is a further EcoSpec category. Threshold values (TPCs) for this category have been defined according to the values that were noted to be specific for each site during the field surveys. Some sites are more productive in terms of fish abundance than others, which is specific for each site.

8.5.1 1_Lephalala

EcoSpecs and TPCs for fish at 1_Lephalala are given in Table 8.47.

Table 8.47: EcoSpecs and TPCs for 1_Lephalala

Metric	EcoSpecs	TPCs		
Species richness & Relative Abundance (RA)	Indicator fish species targeted for the site.	TPCs are triggered if not met on two consecutive sample events.		
	Species	Ref RA*	Ranking^	TPCs
	Labeobarbus marequensis	5	1	The absence of any of these target species over two or more consecutive surveys will be a cause for concern. Overall >60% change in RA over two or more consecutive surveys will be a cause for concern.
	Chiloglanis pretoriae	5	1	
	Labeo cylindricus	3	1	
	Pseudocrenilabrus philander	2	2	
	Clarias gariepinus	1	3	
Alien species	Presence/absence	None	None	>5% of overall abundance
CPUE	Number of individuals sampled per minute of electrofishing effort	0.2	-	<0.2 individuals per min

*RA=Relative abundance.

^1=Rheophilic species; 2=Non-rheophilic species; 3=Eurytopic species

8.5.2 2_Rietfontein

EcoSpecs and TPCs for fish at 2_Rietfontein are given in Table 8.48.

Table 8.48: EcoSpecs and TPCs at 2_Rietfontein

Metric	EcoSpecs	TPCs		
Species richness & Relative Abundance (RA)	Indicator fish species targeted for the site.	TPCs are triggered if not met on two consecutive sample events.		
	Species	Ref RA*	Ranking^	TPCs
	Oreochromis mossambicus	1 (the only species present at the site)	2	The absence of this target species over two or more consecutive surveys will be a cause for concern. RA is not relevant for this site as this is the only expected species at the site.
Alien species	Presence/absence	None	None	>5% of overall abundance
CPUE	Number of individuals sampled per minute of electrofishing effort	1.3	-	<1 individuals per min

*RA=Relative abundance.

^1=Rheophilic species; 2=Non-rheophilic species; 3=Eurytopic species

8.5.3 3_Olifantspruit

EcoSpecs and TPCs for fish at 3_Olifantspruit are given in Table 8.49.

Table 8.49: EcoSpecs and TPCs for 3_Olifantspruit

Metric	EcoSpecs	TPCs		
Species richness & Relative Abundance (RA)	Indicator fish species targeted for the site.	TPCs are triggered if not met on two consecutive sample events.		
	Species	Ref RA*	Ranking^	TPCs
	Labeobarbus marequensis	5	1	The absence of any of these target species over two or more consecutive surveys will be a cause for concern. Overall >60% change in RA over two or more consecutive surveys will be a cause for concern.
	Chiloglanis pretoriae	5	1	
	Labeo cylindricus	3	1	
	Pseudocrenilabrus philander	2	2	
	Enteromius trimaculatus	4	2	
	Enteromius bifrenatus	4	2	
Alien species	Presence/absence	None	None	>5% of overall abundance
CPUE	Number of individuals sampled per minute of electrofishing effort	1.2	-	<1 individuals per min

*RA=Relative abundance.

^1=Rheophilic species; 2=Non-rheophilic species; 3=Eurytopic species

8.5.4 4_Mogalakwena1

EcoSpecs and TPCs for fish at 4_Mogalakwena1 are given in Table 8.50.

Table 8.50: EcoSpecs and TPCs for 4_Mogalakwena1

Metric	EcoSpecs	TPCs		
Species richness & Relative Abundance (RA)	Indicator fish species targeted for the site.	TPCs are triggered if not met on two consecutive sample events.		
	Species	Ref RA*	Ranking^	TPCs
	Labeobarbus marequensis	5	1	The absence of any of these target species over two or more consecutive surveys will be a cause for concern. Overall >60% change in RA over two or more consecutive surveys will be a cause for concern.
	Chiloglanis pretoriae	5	1	
	Labeo cylindricus	3	1	
	Engraulicypris brevianalis	3	1	
	Micralestes acutidens	3	1	
	Pseudocrenilabrus philander	2	2	
	Enteromius trimaculatus	4	2	
	Enteromius bifrenatus	4	2	
	Oreochromis mossambicus	3	3	
Alien species	Presence/absence	None	None	>5% of overall abundance
CPUE	Number of individuals sampled per minute of electrofishing effort	0.6	-	<0.5 individuals per min

*RA=Relative abundance.

^1=Rheophilic species; 2=Non-rheophilic species; 3=Eurytopic species

8.5.5 5_Mogalakwena2

EcoSpecs and TPCs for fish at 5_Mogalakwena2 are given in Table 8.51.

Table 8.51: EcoSpecs and TPCs for 5_Mogalakwena2

Metric	EcoSpecs	TPCs		
Species richness & Relative Abundance (RA)	Indicator fish species targeted for the site.	TPCs are triggered if not met on two consecutive sample events.		
	Species	Ref RA*	Ranking^	TPCs
	Labeobarbus marequensis	4	1	The absence of any of these target species over two or more consecutive surveys will be a cause for concern. Overall >60% change in RA over two or more consecutive surveys will be a cause for concern.
	Chiloglanis pretoriae	5	1	
	Labeo cylindricus	4	1	
	Engraulicypris brevianalis	2	1	
	Pseudocrenilabrus philander	2	2	
	Enteromius trimaculatus	3	2	
	Enteromius bifrenatus	3	2	
	Oreochromis mossambicus	2	3	
Alien species	Presence/absence	None	None	>5% of overall abundance
CPUE	Number of individuals sampled per minute of electrofishing effort	1.1	-	<1 individuals per min

*RA=Relative abundance.

^1=Rheophilic species; 2=Non-rheophilic species; 3=Eurytopic species

8.5.6 8_Nzhelele

EcoSpecs and TPCs for fish at 8_Nzhelele are given in Table 8.52.

Table 8.52: EcoSpecs and TPCs for 8_Nzhelele

Metric	EcoSpecs	TPCs		
Species richness & Relative Abundance (RA)	Indicator fish species targeted for the site.	TPCs are triggered if not met on two consecutive sample events.		
	Species	Ref RA*	Ranking^	TPCs
	Labeobarbus marequensis	4	1	The absence of any of these target species over two or more consecutive surveys will be a cause for concern. Overall >60% change in RA over two or more consecutive surveys will be a cause for concern.
	Chiloglanis pretoriae	5	1	
	Labeo cylindricus	4	1	
	Engraulicypris brevianalis	2	1	
	Pseudocrenilabrus philander	2	2	
	Enteromius trimaculatus	3	2	
	Enteromius viviparus	3	2	
	Enteromius bifrenatus	3	2	
	Coptodon rendalli	3	2	
	Oreochromis mossambicus	4	3	
Alien species	Presence/absence	None	None	>5% of overall abundance
CPUE	Number of individuals sampled per minute of electrofishing effort	2.2	-	<2 individuals per min

*RA=Relative abundance.

^1=Rheophilic species; 2=Non-rheophilic species; 3=Eurytopic species

8.5.7 9_Ṅwaneḍi

EcoSpecs and TPCs for fish at 9_Ṅwaneḍi are given in Table 8.53

Table 8.53: EcoSpecs and TPCs for 9_Ṅwaneḍi

Metric	EcoSpecs	TPCs		
Species richness & Relative Abundance (RA)	Indicator fish species targeted for the site.	TPCs are triggered if not met on two consecutive sample events.		
	Species	Ref RA*	Ranking^	TPCs
	Labeobarbus marequensis	4	1	The absence of any of these target species over two or more consecutive surveys will be a cause for concern. Overall >60% change in RA over two or more consecutive surveys will be a cause for concern.
	Chiloglanis pretoriae	5	1	
	Labeo cylindricus	3	1	
	Labeo molybdinus	3	1	
	Pseudocrenilabrus philander	2	2	
	Enteromius trimaculatus	3	2	
	Enteromius viviparus	3	2	
	Enteromius bifrenatus	3	2	
	Oreochromis mossambicus	3	3	
Alien species	Presence/absence	None	None	>5% of overall abundance
CPUE	Number of individuals sampled per minute of electrofishing effort	2.4	-	<2 individuals per min

*RA=Relative abundance.

^1=Rheophilic species; 2=Non-rheophilic species; 3=Eurytopic species

8.5.8 10_ Latonyanda

EcoSpecs and TPCs for fish at 10_Latonyanda are given in Table 8.54.

Table 8.54: EcoSpecs and TPCs for 10_Latonyanda

Metric	EcoSpecs	TPCs		
Species richness & Relative Abundance (RA)	Indicator fish species targeted for the site.	TPCs are triggered if not met on two consecutive sample events.		
	Species	Ref RA*	Ranking^	TPCs
	Labeobarbus marequensis	4	1	The absence of any of these target species over two or more consecutive surveys will be a cause for concern. Overall >60% change in RA over two or more consecutive surveys will be a cause for concern.
	Chiloglanis pretoriae	5	1	
	Amphilius uranoscopus	4	1	
	Labeo cylindricus	3	1	
	Pseudocrenilabrus philander	2	2	
	Enteromius trimaculatus	3	2	
	Enteromius viviparus	3	2	
	Enteromius bifrenatus	3	2	
	Oreochromis mossambicus	3	3	
Alien species	Presence/absence	None	None	>5% of overall abundance
CPUE	Number of individuals sampled per minute of electrofishing effort	0.9	-	<0.8 individuals per min

*RA=Relative abundance.

^1=Rheophilic species; 2=Non-rheophilic species; 3=Eurytopic species

8.5.9 11_ Mutshindudi

EcoSpecs and TPCs for fish at 11_Mutshindudi are given in Table 8.55.

Table 8.55: EcoSpecs and TPCs for 11_Mutshindudi

Metric	EcoSpecs	TPCs		
Species richness & Relative Abundance (RA)	Indicator fish species targeted for the site.	TPCs are triggered if not met on two consecutive sample events.		
	Species	Ref RA*	Ranking^	TPCs
	Labeobarbus marequensis	4	1	The absence of any of these target species over two or more consecutive surveys will be a cause for concern. Overall >60% change in RA over two or more consecutive surveys will be a cause for concern.
	Chiloglanis pretoriae	4	1	
	Amphilius uranoscopus	3	1	
	Labeo cylindricus	4	1	
	Pseudocrenilabrus philander	2	2	
	Enteromius trimaculatus	3	2	
	Oreochromis mossambicus	3	3	
Alien species	Presence/absence	None	None	>5% of overall abundance
CPUE	Number of individuals sampled per minute of electrofishing effort	0.6	-	<0.5 individuals per min

*RA=Relative abundance.

^1=Rheophilic species; 2=Non-rheophilic species; 3=Eurytopic species

8.5.10 12_Luvuvhu

EcoSpecs and TPCs for fish at 12_Luvuvhu are given in Table 8.56.

Table 8.56: EcoSpecs and TPCs for 12_Luvuvhu

Metric	EcoSpecs	TPCs		
Species richness & Relative Abundance (RA)	Indicator fish species targeted for the site.	TPCs are triggered if not met on two consecutive sample events.		
	Species	Ref RA*	Ranking^	TPCs
	Labeobarbus marequensis	4	1	The absence of any of these target species over two or more consecutive surveys will be a cause for concern. Overall >60% change in RA over two or more consecutive surveys will be a cause for concern.
	Chiloglanis pretoriae	4	1	
	Micralestes acutidens	3	1	
	Labeo cylindricus	4	1	
	Pseudocrenilabrus philander	2	2	
	Enteromius trimaculatus	3	2	
	Oreochromis mossambicus	3	3	
Alien species	Presence/absence	None	None	>5% of overall abundance
CPUE	Number of individuals sampled per minute of electrofishing effort	0.7	-	<0.5 individuals per min

*RA=Relative abundance.

^1=Rheophilic species; 2=Non-rheophilic species; 3=Eurytopic species

8.5.11 13_Mutale1

EcoSpecs and TPCs for fish at 13_Mutale1 are given in Table 8.57.

Table 8.57: EcoSpecs and TPCs for 13_Mutale1

Metric	EcoSpecs	TPCs		
Species richness & Relative Abundance (RA)	Indicator fish species targeted for the site.	TPCs are triggered if not met on two consecutive sample events.		
	Species	Ref RA*	Ranking^	TPCs
	Labeobarbus marequensis	4	1	The absence of any of these target species over two or more consecutive surveys will be a cause for concern. Overall >60% change in RA over two or more consecutive surveys will be a cause for concern.
	Chiloglanis pretoriae	4	1	
	Marcusenius macrolepidotus	1	2	
	Petrocephalus catostoma	1	2	
	Labeo cylindricus	3	1	
	Pseudocrenilabrus philander	2	2	
	Enteromius trimaculatus	3	2	
	Oreochromis mossambicus	1	3	
Alien species	Presence/absence	None	None	>5% of overall abundance
CPUE	Number of individuals sampled per minute of electrofishing effort	1.3	-	<1 individuals per min

*RA=Relative abundance.

^1=Rheophilic species; 2=Non-rheophilic species; 3=Eurytopic species

8.5.12 14_Mutale2

EcoSpecs and TPCs for fish at 14_Mutale2 are given in Table 8.58.

Table 8.58: EcoSpecs and TPCs for 14_Mutale2

Metric	EcoSpecs	TPCs		
Species richness & Relative Abundance (RA)	Indicator fish species targeted for the site.	TPCs are triggered if not met on two consecutive sample events.		
	Species	Ref RA*	Ranking^	TPCs
	Labeobarbus marequensis	4	1	The absence of any of these target species over two or more consecutive surveys will be a cause for concern. Overall >60% change in RA over two or more consecutive surveys will be a cause for concern.
	Chiloglanis pretoriae	3	1	
	Labeo cylindricus	4	1	
	Micralestes acutidens	4	2	
	Pseudocrenilabrus philander	1	2	
	Enteromius trimaculatus	3	2	
	Oreochromis mossambicus	1	3	
Alien species	Presence/absence	None	None	>5% of overall abundance
CPUE	Number of individuals sampled per minute of electrofishing effort	0.5	-	<0.5 individuals per min

*RA=Relative abundance.

^1=Rheophilic species; 2=Non-rheophilic species; 3=Eurytopic species

9 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The Ecological Importance of a river is an expression of its importance to the maintenance of biological diversity and ecological functioning on local and wider scales. Ecological Sensitivity (or fragility) refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred, called resilience (Kleynhans and Louw 2007).

The approach followed by DWS is that if the Ecological Importance and Sensitivity (EIS) is high or very high, the ecological aim should be to improve the condition of the river. However, the causes related to the particular Present Ecological State (PES) should also be considered to determine if improvement is realistic and attainable. This relates to whether the problems in the catchment can be addressed and mitigated. If the EIS evaluated is moderate or low, the ecological aim should be to maintain the river in its PES (Kleynhans and Louw 2007).

Within the Ecological Reserve context, Ecological Categories A to D can be recommended as future states (REC – the Recommended Ecological Category), depending on the EIS and PES. Ecological Categories E and F are regarded as ecologically unacceptable, and remediation is needed (Kleynhans and Louw 2007).

The EIS was assessed using the DWS EcoClassification modules that rate the riparian biota and instream habitats using the scoring system shown in **Table 9.1**.

Table 9.1: Determinants rated to determine EIS

Ecological Importance and Sensitivity Determinants (Kleynhans and Louw 2007)
BIOTA (RIPARIAN & INSTREAM)
Rare & endangered (range: 4=very high - 0 = none)
Unique (endemic, isolated, etc.) (range: 4=very high - 0 = none)
Intolerant (flow & flow related water quality) (range: 4=very high - 0 = none)
Species/taxon richness (range: 4=very high - 1=low/marginal)
RIPARIAN & INSTREAM HABITATS
Diversity of types (4=Very high - 1=marginal/low)
Refugia (4=Very high - 1=marginal/low)
Sensitivity to flow changes (4=Very high - 1=marginal/low)
Sensitivity to flow related water quality changes (4=Very high - 1=marginal/low)
Migration route/corridor (instream & riparian, range: 4=very high - 0 = none)
Importance of conservation & natural areas (range, 4=very high - 0=very low)

Once the scores are assessed, further consideration is given to other factors that help to inform whether mitigation can be practically achieved and is warranted. The other factors considered were:

- The current day flow (Mean Annual Runoff, MAR) as a percentage of the naturalised (reference) MAR (**Table 9.2**).

- The location of the EWR site in relation to (**Figure 9.1**):
    - Important conservation areas, nature reserves and National Parks
    - Source Water Areas (SWA)
    - Groundwater Source Areas (GWSA)
    - High Priority wetlands and Ramsar sites in particular.

Table 9.2: Ecological Categories and scores for hydrology

Site	1_Lephalala	2_Rietfontein	3_Olifantspruit	4_Mogalakwena	5_Mogalakwena	6_Kolope	7_Sand	8_Nzhelele	9_Ìwanedi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale	14_Mutale
Naturalised (MCM)	67.6	0.2	8.1	73.4	193.3	2.1	27.4	99.7	33.5	64.3	127.9	398.5	149.7	154.9
Current (MCM)	56.2	0.1	7.6	53.9	114.3	1.1	23.5	59.6	26.6	47.6	105.5	247.8	138.6	143.6
%nMAR	83	76	94	74	59	51	86	60	80	74	82	62	93	93
Flow Category	B	C	A	C	C/D	D	B	C/D	B/C	C	B	C	A	A

A summary of factors relevant to decisions on EIS are provided for each of the EWR sites in **Sections 9.1 to 9.14.**

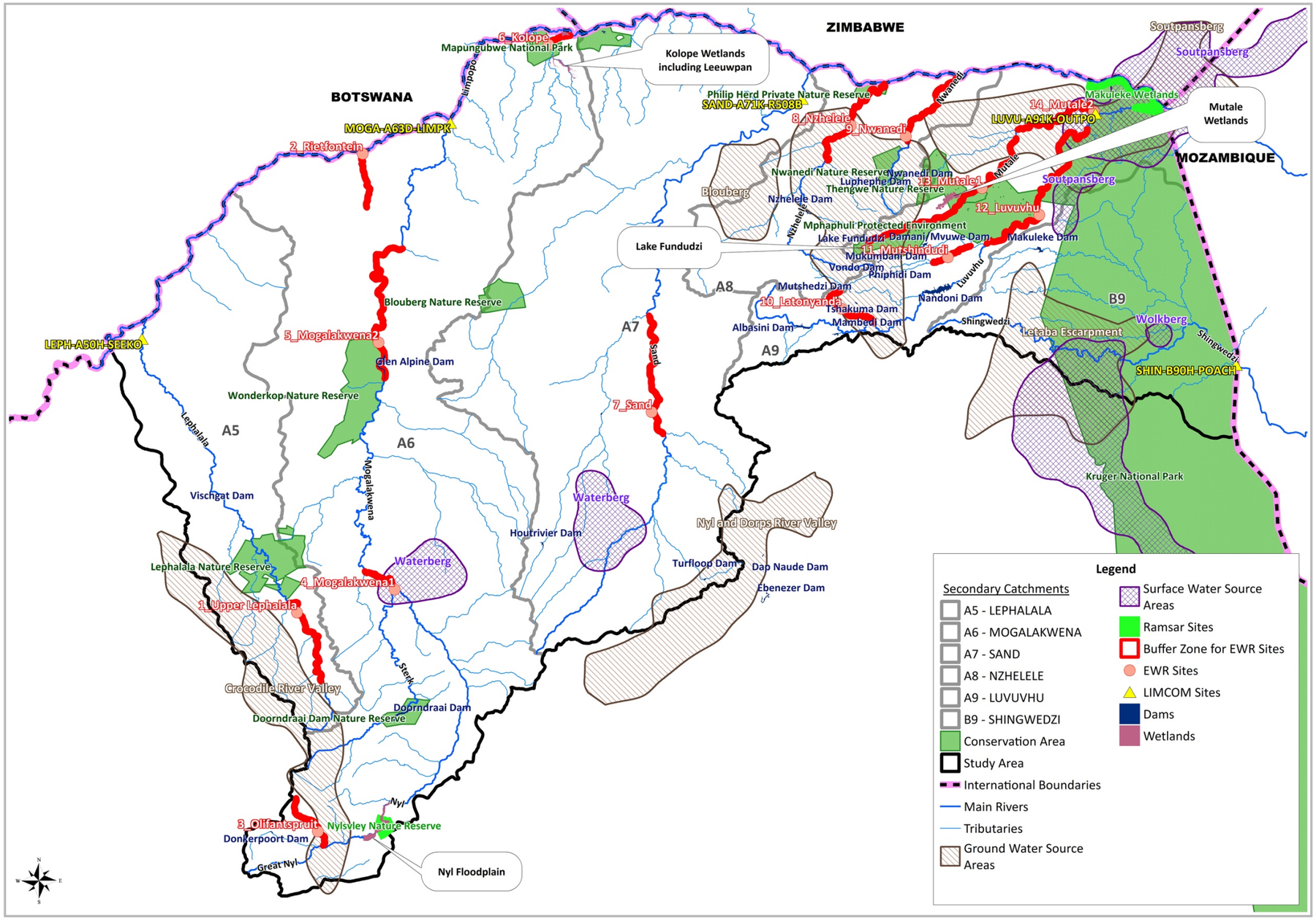


Figure 9.1: EWR sites, Source Water Areas, dams, priority wetlands and conservation areas

9.1 1 Lephalala

The PES of 1_Lephalala is a C category and the river flows close to natural (83% of its natural MAR (nMAR)). The river flows adjacent to a Government Water Scheme Area and through the Lephalala Nature Reserve (**Figure 9.1**). There are no regulating structures upstream nor plans to develop water resource infrastructure upstream. There is a small increase in water use (5%) expected by 2050 and no increase in return flows throughout the year.

The causes and sources of the PES, and projected trends are summarised in **Table 9.3**. All are non-flow related apart from barriers to fish migration. The main issues at this site are exotic plants and fewer than expected fish species, both of which are on a negative trend if current pressures remain.

Table 9.3: Causes and sources of PES, and projected trends at 1_Lephalala

Component	Causes	Sources	Flow or non-flow related	Trends
Water quality	Slight increase in salinity and nutrients.	Irrigation return flows.	Non-flow.	Slight negative (increasing) trend in electrical conductivity & nutrients.
Geomorphology	Sedimentation in pools; bench erosion and trampling.	Localised farming, grazing and roads.	Non-flow.	Absent, geomorphological processes are in balance.
Vegetation	Altered species composition.	Annual and perennial alien plant species.	Non-flow.	Negative because the perennial alien plant species found on site are invasive and will increase / expand if left unchecked.
Invertebrates	Water quality, instream habitat modification.	Potential nutrient enrichment.	Non-flow.	Absent, there were no discernible trends visible in the data.
Fish	Instream barriers blocking migration; high sediment loads.	Sediment management weirs (DWS) and abstraction weirs (landowners).	Flow.	Negative because of instream barriers that fragment habitat and prevent migration so there is no recruitment from downstream.

The ratings given for EIS are provided in **Table 9.4**. Fish were rated HIGH for EIS because of the flow sensitivity of the *Labeo* spp. in the river and also because of a high diversity of good quality fish habitat, in particular refugia, and that these would be sensitive to changes in flow. Vegetation and invertebrates were rated MODERATE for EIS, the only high ratings given to macroinvertebrates for taxon richness and many taxa being sensitive to changes in flow.

The overall EIS rating was **MODERATE** at this site, which means the standard course of action would be to maintain the PES.

However, because the river flows into the Lephalala Nature Reserve a REC half a category higher was put forward to improve the condition of the river by clearing the exotic woody plants, and considering the re-stocking of fish.

Table 9.4: EIS ratings at 1_Lephalala

Metrics	PES (2022) Rating				Comments
	Vegetation	Invertebrates	Fish	Median	
Biota (instream and riparian)					
Rare and endangered	1.50		0.00	0.75	VEG: 1 protected tree species at the National scale: *Boscia albitrunca.* FISH: No rare or endangered fish found. High level of instream barriers inhibits recruitment from downstream. INVERTS: We do not have the information to assess this.
Unique	1.50		0.00	0.75	VEG: *Buxus macowanii* (SA endemic); *Miscanthus junceus* (SnA endemic). FISH: Reference data shows are present but none were sampled. High level of instream barriers inhibits recruitment from downstream. INVERTS: We do not have the information to assess this.
Intolerant (flow and/or water quality)	2.00	3.00	4.00	3	VEG: Aquatic vegetation. FISH: Many fish spp flow habitat specialists, many of which occur in fast shallow habitats. INVERTS: Many taxa dependent on flowing water during part/most of their life cycle.
Taxon richness	1.50	3.00	1.00	1.5	VEG: 26 indigenous riparian and wetland species. FISH: High level of instream barriers inhibits recruitment from downstream. Possible water quality issues from upstream users as well. INVERTS: 62 taxa under natural conditions and 46 under PES (2022).
Instream and riparian habitats					
Diversity	1.50	2.00	4.00	2	VEG: Bedrock channel, woody banks, flood bench flood channel, mixed bedrock / alluvium. FISH: High diversity. INVERTS: Instream habitat dominated by boulders and bedrock, limited GSM and veg mostly comprised of graminoids.
Refugia	1.00	2.00	4.00	2	VEG: Aquatic vegetation. FISH: High level. INVERTS: Habitat types functions moderately well as refuge areas.
Sensitivity to change in flows	0.50	2.00	3.00	2	VEG: Low. FISH: Substrate maintenance is dependent on suitable flows. INVERTS: Habitat not particularly sensitive to flow changes.
Sensitivity to change in water quality	0.50	2.00	2.00	2	VEG: Low. FISH: Relatively large water volumes create a buffer to changes. INVERTS: Water quality and hydrology not changed much. Size of river not particularly sensitive.
Migration route/corridor	0.50	1.00	1.00	1	VEG: Fragmented. FISH: Historically important but large number of instream barriers have drastically decreased the relevance of this watercourse to support meaningful migrations. INVERTS: No instream migratory invertebrate taxa but Odonata may use the riparian zone as a corridor.
Importance of conservation and natural areas	0.50	2.00	3.00	2	VEG: Low. FISH: Much of the catchment area falls within privately owned land with a conservation-based ethos. INVERTS: Unproclaimed natural areas and game farms.
MEDIAN	1.25	2.00	2.50	2	
EIS	MOD	MOD	HIGH	**MOD**	

9.2 2_Rietfontein

The PES of 2_Rietfontein is a B/C category and annual river flows are moderate (76% of nMAR). The river flows through private land that is wilderness areas, private game farms and some agricultural lands. There are no large in channel dams or regulating structures upstream and no plans to develop any water resource infrastructure. There are however a number of small farm dams. The river is linked to, and fed by, a groundwater spring so is quite different to the other EWR sites.

The causes and sources of the PES, and projected trends are summarised in **Table 9.5**. All are non-flow related, apart from salinity. The main issue here is sedimentation of the pools because of trapping and flushing of sediments through farm dams, and also from over the surrounding landscape where there is much bare ground and many dirt roads. The projected trends were stable.

Table 9.5: Causes and sources of PES, and projected trends at 2_Rietfontein

Component	Causes	Sources	Flow or non-flow related	Trends
Water quality	Probable increase in salinity due to non-perennial nature of tributaries.	Evaporation in pools.	Flow.	Absent, mostly fed from groundwater spring.
Geomorphology	Sedimentation of pool habitats.	Localised farming, areas with bare soil, roads and widespread grazing, farm dams.	Non-flow.	Slight negative due to recent dam development upstream.
Vegetation	Altered species composition.	Alien plant species (minimal at this site and limited to annual weed species).	Non-flow.	Neutral, stable trend because the alien plant species present were minimal and mostly annual weeds.
Invertebrates	N/A			
Fish	Upwelling of mineral rich groundwater creates a chemical barrier to most fish.	Natural processes.	Non-flow.	Absent, is a small and stable system, fish population and abundances will fluctuate naturally.

The ratings given for EIS are provided in **Table 9.6**.

This site was given a **MODERATE** rating for EIS overall because most scores given for important biota and sensitive species were low. This means the standard course of action at this site would be to maintain the PES. Since there were no compelling reasons to seek a higher status this was the recommendation that was put forward.

Table 9.6: EIS ratings at 2_Rietfontein

Metrics	PES (2022) Rating				Comments
	Vegetation	Invertebrates	Fish	Median	
Biota (instream and riparian)					
Rare and endangered	1.00		0.00	0.50	VEG: Leadwoods (*Combretum imbirbe*) are protected national trees. FISH: Naturally high salinity limits fish diversity to one species. INVERTS: We do not have the information to assess this. FISH: Naturally high salinity limits fish diversity to one species.
Unique	1.00		0.00	0.50	VEG*: Cyperus sexangularis* is endemic to SA. FISH: Naturally high salinity limits fish diversity to one species. INVERTS: We do not have the information to assess this. FISH: Naturally high salinity limits fish diversity to one species.
Intolerant (flow and/or water quality)	1.00		1.00	1.00	VEG: Wetland sedges and grasses dependent on localised permanent wetness. FISH: Sampled species is highly adaptable to both lentic and lotic conditions. INVERTS: N/A.
Taxon richness	1.00		1.00	1.00	VEG: 15 riparian species. FISH: Only 1 taxon sampled. INVERTS: N/A.
Instream and riparian habitats					
Diversity	4.00		1.00	2.50	VEG: Spring fed and riparian, bedrock controlled areas and alluvial areas, in-channel wetland. FISH/INVERTS: N/A.
Refugia	2.00		2.00	2.00	VEG: Spring fed pools / wetland areas different from rest of dry river. FISH/INVERTS: N/A.
Sensitivity to change in flows	2.00		2.00	2.00	VEG: Marginal zone / wetland species need permanent spring water. FISH/INVERTS: N/A.
Sensitivity to change in water quality	1.00		3.00	2.00	VEG: Potentially to temperature. FISH/INVERTS: N/A.
Migration route/corridor	0.00		0.00	0.00	VEG: Minimal. FISH/INVERTS: N/A.
Importance of conservation and natural areas	3.00		1.00	2.00	VEG: Natural area with wetland habitats in ephemeral systems. FISH/INVERTS: N/A.
MEDIAN	1.00		1.00	1.50	
EIS	LOW		LOW	**MOD**	

9.3 3_Olifantspruit

The PES of 3_Olifantspruit is a C category and the river flows near natural (94% of nMAR). The river flows through a GWSA and is one of the larger tributaries that flow into the Nyl River upstream of the Nyl River Floodplain. There are many private agricultural and animal husbandry farms in the catchment. There are no regulating structures upstream nor plans to develop water resource infrastructure.

The causes and sources of the PES, and projected trends are summarised in **Table 9.7**. All are non-flow related, apart from barriers to fish migration. The main issue at this site was exotic woody plants that were expected to increase in abundance and worsen the ecological condition of the river. Geomorphology and fish also contributed to the moderate PES and were on a negative trajectory because of changes in landuse and barriers to fish migration.

Table 9.7: Causes and sources of PES, and projected trends at 3_Olifantspruit

Component	Causes	Sources	Flow or non-flow related	Trends
Water quality	Moderate increase in salinity and nutrients probably caused by irrigation return flows.	Irrigation return flows.	Non-flow.	Moderate negative (increasing) trend in electrical conductivity & nutrients.
Geomorphology	Increased erosion along channel margins with siltation in pools.	Localised farming, areas with bare soil, roads and widespread grazing; localised farm dams.	Non-flow.	Negative, channel scour and siltation increasing.
Vegetation	Altered species composition.	Alien plant species (high at this site and includes woody perennial species).	Non-flow.	Negative, the perennial alien plant species are invasive and will increase if left unchecked.
	Increased woody cover and abundance.			
Invertebrates	Water quality & instream habitat modification	Potential nutrient enrichment.	Non-flow.	Absent, ASPT stable, slight decrease in total SASS score.
Fish	Degraded water quality.	Surrounding land users/ catchment management.	Non-flow.	Negative, the gauging weir downstream limits migration of fish into the upper reaches, which fish abundance and diversity.
	Instream barriers inhibiting migrations and recruitment from downstream.	Barriers = gauging weir downstream of the site.	Flow.	

The ratings given for EIS are provided in **Table 9.8**. Fish were given a HIGH EIS rating because the species present prefer fast flowing water and are sensitive to reductions in flow, and because of habitats for fish and invertebrates both being sensitive to changes in flow and water quality.

The overall EIS rating was **MODERATE** at this site, which means the standard course of action would be to maintain the PES.

However, because of the importance of this river as an inflowing tributary into the Nyl River Floodplain a half-category higher was put forward along with the recommendation to clear the exotic woody plants, and to prevent abstraction of water from this river that is flowing so close to natural. This will maintain inflows into the Nyl River Floodplain from this river that are important for the maintenance of this Ramsar site. Similar restrictions should be put on developments of the other inflowing tributaries.

Table 9.8: EIS ratings at 3_Olifantspruit

Metrics	PES (2022) Rating				Comments
	Vegetation	Invertebrates	Fish	Median	
Biota (instream and riparian)					
Rare and endangered	0.00		0.00	0.00	VEG: None. FISH: Reference data show there are but none were sampled. INVERTS: We do not have the information to assess this.
Unique	1.00		0.00	0.50	VEG: *Combretum erythrophyllum* is endemic to SnA. FISH: Reference data show there are but none were sampled. INVERTS: We do not have the information to assess this.
Intolerant (flow and/or water quality)	0.50	3.00	4.00	3.00	VEG: Marginal zone sedges & grasses. FISH: Many fish are flow habitat specialists, many preferring fast shallow habitats. INVERTS: Many taxa dependent on flowing water during part/most of their life cycle.
Taxon richness	2.00	2.00	1.00	2.00	VEG: 24 indigenous riparian and wetland species. FISH: Reference data show high values but samples collected were less diverse. INVERTS: 52 taxa under natural conditions and 31 under PES (2022).
Instream and riparian habitats					
Diversity	1.00	2.00	3.00	2.00	VEG: Woody banks and floodplain, rocky narrow marginal zone, reed beds. FISH: High level. INVERTS: Instream habitat dominated by cobbles, limited GSM and veg.
Refugia	0.00	2.00	3.00	2.00	VEG: None. FISH: High level. INVERTS: Habitat types functions moderately well as refuge areas.
Sensitivity to change in flows	0.00	3.00	4.00	3.00	VEG: None. FISH: Substrate maintenance is dependent on suitable flows. INVERTS: Habitat is sensitive to flow changes.
Sensitivity to change in water quality	0.00	3.00	4.00	3.00	VEG: None. FISH: Relatively small watercourse and therefore limited buffer capacity to tolerate changes. INVERTS: Change in hydrology will negatively impact the water quality of the system.
Migration route/corridor	0.50	1.00	1.00	1.00	VEG: Fragmented. FISH: A generally open and longitudinally connected watercourse that would promote migration movements in support of breeding and dispersal. There is a weir downstream of the site. INVERTS: No instream migratory invertebrate taxa but Odonata may use the riparian zone as a corridor.
Importance of conservation and natural areas	0.00	2.00	2.00	2.00	VEG: None. FISH: Much of the catchment area falls within natural areas that cumulatively act to conserve the resource. INVERTS: Unproclaimed natural areas and game farms.
MEDIAN	0.25	2.00	2.50	2.00	
EIS	LOW	MOD	HIGH	**MOD**	

9.4 4_Mogalakwena1

The PES of 4_Mogalakwena is a C category and the annual river flows are moderate (74% of nMAR). It is downstream of the confluence with the Sterk River where Doorndraai Dam is located, which regulates the flow of the Sterk River. With the future developments planned upstream of the EWR site there is expected to be an increase in return flows by 2050 that is going to increase the dry season flows significantly and leave the wet season flows relatively unaffected.

The causes and sources of the PES, and projected trends are summarised in **Table 9.9**. All are non-flow related apart from the encroachment of reeds and terrestrialisation by *Dichrostachy cinerea.* These two aspects contribute negatively to the overall PES and are unlikely to be resolved through changes in flow because the releases from Doorndraai Dam are part of the current operation of water resources in the basin. Exotic plants also contributed negatively to the score and are on a negative trajectory because the invasive species will spread if left unchecked.

Table 9.9: Causes and sources of PES, and projected trends at 4_Mogalakwena1

Component	Causes	Sources	Flow or non-flow related	Trends
Water quality	Probable increase in salinity and nutrients.	Mining and WWTW effluents and irrigation return flows.	Non-flow.	Probably negative (increasing) trend due to cumulative impacts of WWTW and mining upstream of the site.
Geomorphology	Sedimentation of pools and low velocity habitat, trampling, bank disturbance where river is accessed.	Localised farming, settlements with bare soil, roads and widespread grazing. Localised farm dams in upper catchment.	Non-flow.	Negative, bank erosion and habitat modification is ongoing.
Vegetation	Altered species composition.	Annual and perennial alien plant species.	Non-flow.	Negative, because the perennial alien plant species are invasive and will increase if left unchecked.
	Increased reed density and cover.	Flow regulation and reduction, flood peak reduction.	Flow.	
	Bush encroachment of flood features (mainly *D. cinerea).*		Flow.	
Invertebrates	Water quality, instream habitat modification.	Nutrient enrichment from upstream settlements, towns, agriculture, livestock watering, mining.	Non-flow.	Negative, decrease in total SASS scores and number of taxa, ASPT is more stable.
Fish	Sedimentation of substrates.	Catchment land use (mining & informal residential sectors), with poor catchment management.	Non-flow.	Negative trends in water quality and geomorphology, eroding river banks.
	Water quality degradation (general & turbidity).			

The ratings given for EIS are provided in **Table 9.10**. Fish were rated with a HIGH EIS because of the fish present that prefer fast flowing water, the high quality fish habitat and refugia, and the river channel being relatively free from migration barriers, so opening up opportunity for fish migration. Vegetation was given a LOW EIS and invertebrates a MODERATE EIS. The overall EIS was **MODERATE**, meaning the standard course of action would be to maintain the PES. Since there were no compelling reasons to seek an improved status this was the recommendation put forward. The outcome of the Future water resource developments are assessed and explained in the EWR Report – River Assessment (Volume 3): Ecological Water Requirements.

Table 9.10: EIS ratings at 4_Mogalakwena1

Metrics	PES (2022) Rating				Comments
	Vegetation	Invertebrates	Fish	Median	
Biota (instream and riparian)					
Rare and endangered	0.00		0.00	0.00	VEG: None. FISH: None were captured in the samples collected. INVERTS: We do not have the information to assess this.
Unique	1.00		0.00	0.50	VEG: *Combretum erythrophyllum* (SnA endemic). FISH: None were captured in the samples collected. INVERTS: We do not have the information to assess this.
Intolerant (flow and/or water quality)	0.00	3.00	4.00	3.00	VEG: None. FISH: Many fish species are flow habitat specialists, many preferring fast shallow habitats. INVERTS: Many taxa are dependent on flowing water for part of their life cycles.
Taxon richness	1.00	2.00	2.00	2.00	VEG: There are 16 indigenous riparian species. FISH: Taxon richness was lower than expected. INVERTS: There are 53 taxa under natural conditions and 41 under PES (2022).
Instream and riparian habitats					
Diversity	2.50	2.00	3.00	2.50	VEG: Pool-riffle/run, woody banks, with flood bench and floodplain, complex at confluence. FISH: High diversity. INVERTS: Instream habitat dominated by cobbles, GSM and marginal vegetation mostly graminoids.
Refugia	0.00	2.00	4.00	2.00	VEG: None. FISH: High level. INVERTS: Moderate refugia available given the composition of the existing instream habitat.
Sensitivity to change in flows	0.00	2.00	4.00	2.00	VEG: None. FISH: Substrate maintenance is dependent on suitable flows. INVERTS: Some habitat sensitive to flow changes.
Sensitivity to change in water quality	0.00	3.00	4.00	3.00	VEG: None. FISH: Relatively small watercourse and therefore limited buffer capacity to tolerate changes. INVERTS: Some habitat sensitive to water quality related flow changes.
Migration route/corridor	1.00	1.00	3.00	1.00	VEG: Corridor functionality intact in places but community is fragmented. FISH: A generally open and longitudinally connected watercourse that would promote migration movements in support of breeding and dispersal. INVERTS: No instream migratory invertebrate taxa but Odonata may use the riparian zone as a corridor.
Importance of conservation and natural areas	0.50	1.00	3.00	1.00	VEG: Low. FISH: Much of the catchment area falls within natural areas that cumulatively act to conserve the resource. INVERTS: Open areas present, may be of importance on a local scale.
MEDIAN	0.25	2.00	3.00	2.00	
EIS	LOW	MOD	HIGH	**MOD**	

9.5 5_Mogalakwena2

The PES of 5_Mogalakwena is a C category and the annual river flows are approximately half of natural (59% of nMAR). It is situated downstream of Glen Alpine Dam and the upper reaches flow adjacent to Wonderkop Nature Resevrve. There are plans to develop water resources in the catchment upstream by 2050 that are expected to increase return flows into, and releases made from Glen Alpine Dam, in

the dry season. Dry season flows are expected to be higher and the wet season flows slightly lower because of increased water use from Glen Alpine Dam where storage capacity will be increased.

The causes and sources of the PES, and projected trends are summarised in **Table 9.11**. Many of the issues have to do with changes in the flow of water and sediment because of the close proximity to the dam upstream and all are on a negative trajectory. Opportunities to improve the impacts of the dam are limited and the changes predicted in response to the planned increases in water use are modelled in DRIFT. The results of the DRIFT assessment are explained in the EWR Report - River Assessment (Volume 3): Ecological Water Requirements.

Table 9.11: Causes and sources of PES, and projected trends at 5_Mogalakwena

Component	Causes	Sources	Flow or non-flow related	Trends
Water quality	Increase in salinity, no trends in nutrients, cold water discharges and possible anoxic outflow from Glen Alpine Dam.	Urban sprawl upstream of dam, operations of the dam (bottom outlet).	Non-flow.	Negative (increasing) trend in salinity, none in nutrients. Strong seasonality in salinity.
Geomorphology	Channel narrowing, bar stabilisation, sedimentation of pools.	~5k downstream of Glen Alpine dam trapping coarse bedload and reducing flood flows.	Non-flow.	Negative, siltation and channel contraction is likely to continue/worsen.
	Trampling and bank erosion.	Localised overgrazing and trampling.		
Vegetation	Altered species composition.	Annual and perennial alien plant species.	Non-flow.	Negative because the perennial alien plant species are invasive and will increase if left unchecked.
	Altered species composition.	Flow regulation and reduction, flood peak reduction.	Flow.	
Invertebrates	Water quality impacts.	Human settlements, livestock watering, agriculture.	Non-flow.	Absent, no discernible trends visible in the data.
	Flow modification.	Downstream of Glen Alpine Dam.	Flow.	
Fish	Sedimentation of substrates. Water quality degradation (general turbidity from catchment).	Catchment land use (agriculture).	Non-flow.	Negative, continued degrading water quality and habitat conditions.

The ratings given for EIS are provided in **Table 9.12**. Fish were rated with a HIGH EIS because of the fish present that prefer fast flowing water, the high quality fish habitat and refugia, and the river channel being relatively free from migration barriers, so opening up opportunity for fish migration. Vegetation and invertebrates were given a MODERATE EIS. The overall EIS was **MODERATE**, meaning the standard course of action would be to maintain the PES. Since there were no compelling reasons to seek an improved status this was the recommendation put forward.

Table 9.12: EIS ratings at 5_Mogalakwena

Metrics	PES (2022) Rating				Comments
	Vegetation	Invertebrates	Fish	Median	
Biota (instream and riparian)					
Rare and endangered	3.00		0.00	1.50	VEG: 3 Nationally protected species: Apple Leaf (*Philenoptera violacea*), Leadwood (*Combretum imberbe*) and Camel Thorn (*Vachellia erioloba*). FISH: None were captured in the samples collected. INVERTS: We do not have the information to assess this.
Unique	1.00		0.00	0.50	VEG: *Schotia brachypetala* (SnA endemic). FISH: None were captured in the samples collected. INVERTS: We do not have the information to assess this.
Intolerant (flow and/or water quality)	2.00	3.00	4.00	3.00	VEG: Marginal zone grasses (*Ischaemum fasciculatum*) and sedges (*Juncus lomatophyllus*). FISH: Many fish species are flow habitat specialists, many prefer fast shallow habitats. INVERTS: Many taxa dependent on flowing water during part/most of their life cycle.
Taxon richness	1.50	2.00	3.00	2.00	VEG: There are 22 indigenous riparian species. FISH: Taxon richness was lower than expected. INVERTS: There are 51 taxa under natural conditions and 43 under PES (2022).
Instream and riparian habitats					
Diversity	2.00	2.00	3.00	2.00	VEG: Pool-riffle/run, woody banks, with flood bench. FISH: High diversity. INVERTS: Instream habitat dominated by cobbles, GSM, some graminoids.
Refugia	0.00	2.00	4.00	2.00	VEG: None. FISH: High level. INVERTS: Moderate refugia available given the composition of the existing instream habitat.
Sensitivity to change in flows	1.00	2.00	4.00	2.00	VEG: Marginal zone. FISH: Substrate maintenance is dependent on suitable flows. INVERTS: Some habitat sensitive to flow changes.
Sensitivity to change in water quality	1.00	3.00	4.00	3.00	VEG: Marginal zone. FISH: Relatively small watercourse and therefore limited buffer capacity to tolerate changes. INVERTS: Some habitat sensitive to water quality related flow changes.
Migration route/corridor	1.50	1.00	3.00	1.50	VEG: Corridor functionality generally intact. FISH: A generally open and longitudinally connected watercourse that would promote migration movements in support of breeding and dispersal. INVERTS: No instream migratory invertebrate taxa but Odonata may use the riparian zone as a corridor.
Importance of conservation and natural areas	2.00	1.00	3.00	2.00	VEG: Moderate due to protected species and stability over time. FISH: Much of the catchment area falls within natural areas that cumulatively act to conserve the resource. INVERTS: Open areas present, may be of importance on a local scale.
MEDIAN	1.50	2.00	3.00	2.00	
EIS	MOD	MOD	HIGH	**MOD**	

9.6 6_Kolope

The PES of 6_Kolope is a C category and annual flows are approximately half of natural (51% nMAR). It is situated in Mapungubwe National Park and is associated with two important wetlands, Leeuwpan and the Maloutswa Floodplain at the confluence with the Limpopo River. There are no plans to develop

water resources in the catchment and there are no large dams or water regulating structures upstream. There are two gabion dams built across the channel, one upstream and one downstream of the EWR site that are installed to help deal with channel incision.

The causes and sources of the PES, and projected trends are summarised in **Table 9.13**. All are non-flow related, apart from water quality. Channel incision and river bank erosion are the two main issues at this site and it remains to be seen whether the gabion dam walls will reduce the negative trend in geomorphological condition.

Table 9.13: Causes and sources of PES, and projected trends at 6_Kolope

Component	Causes	Sources	Flow or non-flow related	Trends
Water quality	Probable increase in salinity due to non-perennial nature of tributaries.	Evaporation and increase in salinity.	Flow.	Absent, no data.
Geomorphology	Incision of the channel and bank erosion.	Widespread trampling and bank erosion.	Non-flow.	Negative, bank and incision is likely to increase.
Vegetation	Altered species composition.	Alien plant species (minimal at this site and limited to annual weed species).	Non-flow.	Absent, because the alien plant species present were minimal and mostly annual weeds.
	Reduced woody cover and abundance.	High impacts by elephants.	Non-flow.	
Invertebrates	N/A.			N/A, was no surface water.
Fish	Sedimentation is a major driver within the system. Assumed high turbidity levels also due to this.	Catchment land use that aggravates soil erosion, smothering of habitat and increase in turbidity.	Non-flow.	N/A, was no surface water.

The ratings given for EIS are provided in **Table 9.14**. Vegetation was given a LOW EIS rating and fish a MODERATE rating, that resulted in a **MODERATE** EIS for the site overall. The normal course of action would therefore be to maintain the PES.

This rating is based on the biota and habitat conditions at the site[5] and does not take into account the importance of this non-perennial river, the largest in the Mapungubwe National park, which receives inflows from Leeuwpan and carries these and floods from the Kolope River upstream down to the Maloutswa floodplain in the wet season. It is recommended that the efforts to curtail channel incision continue and with improvements in bank stability the riparian vegetation should recover and re-establish. Both these improvements are expected to increase the overall status of the site to at least a B/C category. In addition, further damming or other development of water resource infrastructure should be prevented to maintain the current day flows that flow down the river and flood the floodplain in the wet season.

[5] The EIS rating given for fish was based on the historical data.

Table 9.14: EIS ratings at 6_Kolope

Metrics	PES (2022) Rating				Comments
	Vegetation	Invertebrates	Fish	Median	
Biota (instream and riparian)					
Rare and endangered	2.00		1.00	1.50	VEG: 2 protected tree species at the National scale: *Combretum imberbe* and *Philenoptera violacea*. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: We do not have the information to assess this.
Unique	0.00		1.00	0.50	VEG: None. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: We do not have the information to assess this.
Intolerant (flow and/or water quality)	0.00		4.00	2.00	VEG: None. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: N/A.
Taxon richness	1.00		2.00	1.50	VEG: 11 indigenous riparian and wetland species. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: N/A.
Instream and riparian habitats					
Diversity	1.00		2.00	1.50	VEG: Woody banks and alluvial bench, ephemeral alluvial channel. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: N/A.
Refugia	2.00		2.00	2.00	VEG: Protected riparian tree species. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: N/A.
Sensitivity to change in flows	0.00		3.00	1.50	VEG: None. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: N/A.
Sensitivity to change in water quality	0.00		4.00	2.00	VEG: None. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: N/A.
Migration route/corridor	0.50		2.00	1.25	VEG: Fragmented. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: N/A.
Importance of conservation and natural areas	4.00		3.00	3.50	VEG: Mapungubwe National Park. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: N/A.
MEDIAN	0.75		2.00	1.50	
EIS	LOW		MOD	**MOD**	

9.7 7_Sand

The PES of 7_Sand is a C category and the river flows close to natural (86% of nMAR). It flows through privately owned land. There are plans to transfer water from Seshego Dam into the Sand catchment via the Bloed River for Polokwane, which will increase return flows that will flow through the EWR site by 2050. Some of these return flows will be taken up by irrigators and the remainder are expected to increase the dry and wet season flows in the river.

The causes and sources of the PES, and projected trends are summarised in **Table 9.15**. The main issues at this non-perennial EWR site are non-flow related. Most concerning was water quality but geomorphology and riparian vegetation also scored poorly toward the PES.

Table 9.15: Causes and sources of PES, and projected trends at 7_Sand

Component	Causes	Sources	Flow or non-flow related	Trends
Water quality	No data, probably negative trend in salts and nutrients.	WWTW and mining effluents around Polokwane & Seshego about 60km upstream of EWR site.	Non-flow.	No data, probably negative trend in salts and nutrients.
Geomorphology	Increased silt load, bed and bank disturbance.	Widespread grazing, settlements, roads; sand mining; river access and trampling.	Non-flow.	Absent, geomorphic processes are in balance.
Vegetation	Altered species composition.	Annual and perennial alien plant species.	Non-flow.	Stable, because the alien plant species present were minimal and most annual weeds.
Invertebrates	N/A.			N/A, was no surface water.
Fish	N.A.			N/A, was no surface water.

The ratings given for EIS are provided in **Table 9.16**. Vegetation was rated with a LOW EIS and fish a MODERATE EIS, together this resulted in a **MODERATE** EIS for the site overall. The higher scores given for fish were based on the fish population expected to occur in the river because there was no flow in the river at the time of the fish surveys. The standard course of action would therefore be to maintain the PES.

There are no compelling reasons to seek a higher status at this site but the outcome of the Future water resource developments planned are assessed and explained in the EWR Report - River Assessment (Volume 3): Ecological Water Requirements.

Table 9.16: EIS ratings at 7_Sand

Metrics	PES (2022) Rating				Comments
	Vegetation	Invertebrates	Fish	Median	
Biota (instream and riparian)					
Rare and endangered	0.00		1.00	0.50	VEG: None. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: We do not have the information to assess this.
Unique	1.00		1.00	1.00	VEG: *Combretum erythrophyllum* (SnA endemic). FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: We do not have the information to assess this.
Intolerant (flow and/or water quality)	0.00		4.00	2.00	VEG: None. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: N/A.
Taxon richness	1.00		2.00	1.50	VEG: 15 indigenous riparian species. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: N/A.
Instream and riparian habitats					
Diversity	1.00		2.00	1.50	VEG: ephemeral sandy / bedrock channel, woody banks, flood bench (consolidated). FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: N/A
Refugia	0.00		2.00	1.00	VEG: None. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: N/A
Sensitivity to change in flows	0.00		4.00	2.00	VEG: None. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: N/A
Sensitivity to change in water quality	0.00		4.00	2.00	VEG: None. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: N/A
Migration route/corridor	1.50		2.00	1.75	VEG: Corridor functionality generally intact. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: N/A.
Importance of conservation and natural areas	0.50		2.00	1.25	VEG: Low. FISH: As "natural" is based on reference data, the "PES (2022)" is matched, but with low confidence. INVERTS: N/A.
MEDIAN	0.25		2.00	1.50	
EIS	LOW		MOD	**MOD**	

9.8 8_Nzhelele

The PES of 8_Nzhelele is a C category and annual flows are approximately half of natural (59% of nMAR). It is situated downstream of Nzhelele Dam and flows out from a Government Water Area into the Philip Herd Private Nature Reserve at the confluence with the Limpopo River. There is expected to be an increase in water use by 2050 and no increase in return flows that will reduce flow throughout the year.

The causes and sources of the PES, and projected trends are summarised in **Table 9.17**. There is a mixture of flow and non-flow related issues affecting the PES. The main issue is the large amount of fine sediment from the incremental catchment upstream but water quality, riparian vegetation and

invertebrates also contributed moderate scores to the PES. The trends were neutral or slightly negetaive so the expectation was that all things being equal the status quo would remain.

Table 9.17: Causes and sources of PES, and projected trends at 8_Nzhelele

Component	Causes	Sources	Flow or non-flow related	Trends
Water quality	High salinity.	Evaporation & irrigation return flows.	Flow.	Negative trend at Nzhelele Dam in electrical conductivity & nutrients. Strong seasonality in electrical conductivity.
	High nutrients.	Irrigation return flows.	Non-flow.	
Geomorphology	Increased fine sediment input; bank erosion.	Increased fine sediment due to agriculture, bare areas, grazing and bank erosion; Nzhelele Dam trapping bedload; trampling by game.	Non-flow.	Slight negative with ongoing bank erosion and siltation.
Vegetation	Altered species composition.	Annual and perennial alien plant species.	Non-flow.	Trend stable, the alien plant species present were minimal and mostly annual weeds.
	Reduced non-woody cover and increased in-channel shrubs.	Flow regulation and reduction, flood peak reduction.	Flow.	
Invertebrates	Water quality, instream habitat modification.	Nutrient enrichment, agriculture.	Non-flow.	Absent, no discernible trends visible in the data.
Fish	Sedimentation of substrates.	Catchment land use (agriculture).	Non-flow.	Absent, strong and diverse fish community, diverse habitat features.
	Instream barriers that inhibit migrations, spawning and recruitment.	Weir downstream of EWR site.	Flow.	

The ratings given for EIS are provided in **Table 9.18**. Vegetation was given a MODERATE EIS rating and invertebrates and fish a HIGH EIS rating, because of high taxon richness and many of the taxa present being dependent on good flow in the river. Habitat conditions for fish and invertebrates were also rated high because of sensitivity to changes in flow and water quality. The overall EIS was **MODERATE**, which would mean the aim would be to maintain the PES. The flow related issues are unlikely to be improved as the current use of water is unlikely to change and is going to worsen if the predictions on water use prevail. Since the Nzhelele River flows into the Philip Herd Private Nature Reserve and then directly into the Limpopo River it would be beneficial if the ecological condition of the river could be improved. The only opportunity for this appears to be water quality, related to the irrigation return flows, which would have a knock-on improvement for invertebrates. Together, the improved water quality and invertebrates scores could lift the overall condition by half a category to a B/C. The outcome of the Future water use is assessed and explained in the **EWR Report - River Assessment (Volume 3): Ecological Water Requirements**.

Table 9.18: EIS rating for 8_Nzhelele

Metrics	PES (2022) Rating				Comments
	Vegetation	Invertebrates	Fish	Median	
Biota (instream and riparian)					
Rare and endangered	1.50		0.00	0.75	VEG: Leadwood (*Combretum imbirbe*) and Apple Leaf (*Philonoptera violaceae*) are protected national tree species. FISH: Reference data indicate there may be but none was captured in the samples. INVERTS: We do not have the information to assess this.
Unique	0.00		0.00	0.00	VEG: None. FISH: Reference data indicate there may be but none was captured in the samples. INVERTS: We do not have the information to assess this.
Intolerant (flow and/or water quality)	1.00	3.00	4.00	3.00	VEG: Wetland sedges and grasses. FISH: Many fish species are flow habitat specialists, many prefer fast shallow habitats. INVERTS: Many taxa are dependent on flowing water for part of their life cycle.
Taxon richness	1.50	3.00	3.00	3.00	VEG: There are 25 indigenous riparian species. FISH: Reference data and samples collected indicator high fish diversity. INVERTS: There are 58 taxa under natural conditions and 42 under PES (2022).
Instream and riparian habitats					
Diversity	2.00	2.00	3.00	2.00	VEG: Pool-riffle/run, reed beds and woody banks, with flood bench and channels. FISH: High diversity. INVERTS: Instream habitat dominated by cobbles, GSM and graminoids.
Refugia	0.00	2.00	3.00	2.00	VEG: None. FISH: High level. INVERTS: Moderate refugia available given the composition of the existing instream habitat.
Sensitivity to change in flows	1.00	2.00	4.00	2.00	VEG: Marginal zone species. FISH: Substrate maintenance is dependent on suitable flows. INVERTS: Some habitats are sensitive to flow changes.
Sensitivity to change in water quality	1.00	3.00	4.00	3.00	VEG: Potentially to nutrients for e.g. reeds. FISH: Relatively small water volumes that limits buffer capacity to changes. INVERTS: Some habitat sensitive to water quality related flow changes.
Migration route/corridor	2.00	2.00	2.00	2.00	VEG: Moderately intact. FISH: Historically important but instream barriers have decreased the relevance of this watercourse to support migrations. INVERTS: Paleomonidae occur within the system, as well as Odonata that may use the riparian zone as a corridor.
Importance of conservation and natural areas	1.50	3.00	3.00	3.00	VEG: Upstream Reserve and intact corridor, with game farming in the area. FISH: Much of the catchment area falls within privately owned land with a conservation-based ethos. INVERTS: Within a regional conservation area, the Maremani Nature Reserve.
MEDIAN	1.25	2.50	3.00	2.00	
EIS	MOD	HIGH	HIGH	**MOD**	

9.9 9_Ṅwaneḍi

The PES of 9_Ṅwaneḍi is a C category and the river flows close to natural (80% of nMAR). It is situated downstream of Ṅwaneḍi, Luphephe and Cross Dams and flows out from, and adjacent to, two different Government Water Scheme Areas into the Limpopo River. There are nature reserves up- and downstream of the EWR site and along the Limpopo River in this important conservation area around

the confluence. There is expected to be an increase in water use by 2050 and no increase in return flows that will reduce flow throughout the year.

The causes and sources of the PES, and projected trends are summarised in **Table 9.19**. There is a mixture of flow and non-flow related issues. The main issue is bank erosion, siltation in the channel and channel incision due to flow modification and landuse practices that are on a negative trend. Moderate scores were given for water quality, vegetation and invertebrates and all the impacts on PES were related to agricultural landuse in one way or another.

Table 9.19: Causes and sources of PES, and projected trends at 9_Ṅwaneḍi

Component	Causes	Sources	Flow or non-flow related	Confidence
Water quality	High salinity downstream of EWR site and increasing nutrients trend.	Irrigated agriculture in riparian zone.	Non-flow.	Absent based on a limited data at site.
Geomorphology	Bank erosion; siltation, channel access, channel incision and armouring.	Trampling, overgrazing; reduced longitudinal sediment transport due to upstream dams.	Flow and non-flow.	Negative, channel and bank erosion are ongoing.
Vegetation	Altered species composition.	Annual and perennial alien plant species.	Non-flow.	Absent, trend is stable because the alien plant species present were minimal and mostly annual weeds.
	Reduced woody cover along banks.	Agricultural encroachment and wood removal.	Non-flow.	
Invertebrates	Water quality.	Agriculture.	Non-flow.	Absent, no discernible trends present with variable total SASS and ASPT scores.
	Flow modification.	Upstream dam.	Flow.	
Fish	Sedimentation of substrates. Solid waste that deteriorates water quality. Alien vegetation.	Catchment land use (agriculture).	Non-flow.	Negative, continued reduction in habitat conditions for fish and are barriers to migration.
	Instream barriers that inhibit migrations for both spawning and recruitment.	A dam upstream of the EWR site. Other migratory barriers are poorly-designed road crossings.	Flow.	

The ratings given for EIS are provided in **Table 9.20**. Vegetation was given a LOW EIS rating while invertebrates and fish both received a MODERATE EIS rating, having higher scores for taxon richness and sensitivity to changes in flow and water quality. High ratings were given for diversity of habitat and refugia for fish and invertebrate habitat being sensitive to changes in flow. The overall EIS rating was **MODERATE**, therefore the aim would be to maintain the PES. The flow related issues are unlikely to improve as the current use of water is unlikely to change and is going to worsen if the predictions on water use prevail. Since the Ṅwaneḍi River flows through the Adwen and JD Storm Private Nature Reserves and then directly into the Limpopo River it would be beneficial if the ecological condition of the river could be improved however options are limited due to well established water use and agricultural practices. The outcome of the Future water use is assessed and explained in the EWR Report - River Assessment (Volume 3): Ecological Water Requirements.

Table 9.20: EIS ratings for 9_Ṅwaneḍi

Metrics	PES (2022) Rating				Comments
	Vegetation	Invertebrates	Fish	Median	
Biota (instream and riparian)					
Rare and endangered	1.00		0.00	0.50	VEG: Matumi (*Breonadia salicina*) is a protected national tree species. FISH: Reference data suggest there may be but none were captured in the samples taken. INVERTS: We do not have the information to assess this.
Unique	1.00		0.00	0.50	VEG: *Buxus macowanii* (SA endemic) and *Schotia brachypetala* (SnA endemic). FISH: Reference data suggest there may be but none were captured in the samples taken. INVERTS: N/A.
Intolerant (flow and/or water quality)	0.50	3.00	4.00	3.00	VEG: Mostly absent. FISH: Many fish species are flow habitat specialists, many prefer fast shallow habitats. INVERTS: Many taxa dependent on flowing water for part of their life cycle.
Taxon richness	1.50	3.00	3.00	3.00	VEG: There are 21 indigenous riparian species. FISH: Reference data and samples collected showed comparable diversity. INVERTS: There are 63 taxa under natural conditions and 41 under PES (2022).
Instream and riparian habitats					
Diversity	1.50	2.00	3.00	2.00	VEG: Pool-riffle/run, woody banks, with flood bench. FISH: High diversity. INVERTS: Instream habitat dominated by cobbles, GSM, some graminoids and other broadleaved marginal vegetation.
Refugia	0.00	2.00	3.00	2.00	VEG: None. FISH: High level. INVERTS: Moderate refugia available given the composition of the existing instream habitat.
Sensitivity to change in flows	0.50	2.00	2.00	2.00	VEG: Mostly absent. FISH: Substrate maintenance is dependent on suitable flows. INVERTS: Some habitat sensitive to flow changes.
Sensitivity to change in water quality	0.00	3.00	2.00	2.00	VEG: None. FISH: Relatively small watercourse and therefore limited buffer capacity to tolerate changes. INVERTS: Some habitat sensitive to water quality related flow changes.
Migration route/corridor	2.50	2.00	1.00	2.00	VEG: Moderately intact corridor functionality. FISH: Many instream barriers, including a large impoundment upstream that block migration of fish. INVERTS: Paleomonidae occur within the system, as well as Odonata that may use the riparian zone as a corridor.
Importance of conservation and natural areas	0.50	1.00	1.00	1.00	VEG: Low. FISH: Low - much of the catchment is commercial farmland. INVERTS: Open areas present.
MEDIAN	0.75	2.00	2.00	2.00	
EIS	LOW	MOD	MOD	**MOD**	

9.10 10_Latonyanda

The PES of 10_Latonyanda is a C category and the annual river flows are moderate (74% of nMAR). It is situated in Entabeni State Forest and flows through a Government Water Scheme Area into the Luvuvhu River upstream of Nanḍoni Dam. There are no regulating structues upstream nor plans to develop water resource infrastructure in the catchment.

The causes and sources of the PES, and projected trends are summarised in **Table 9.21**. All of the issues at this are non-flow related and are linked to afforestation. Vegetation and geomorphology scored most poorly with high levels of in-channel sediments contributing to poor habitat conditions and there being many exotic woody plants from the surrounding forest. Both were on a negative trajectory that is unlikely to change unless the commercial forest is removed.

Table 9.21: Causes and sources of PES, and projected trends at 10_Latonyanda

Component	Causes	Sources	Flow or non-flow related	Confidence
Water quality	Increasing & seasonality in salinity, slight increases in nutrients, impacts of urban sprawl at EWR site.	Possible forestry activities upstream of sampling site.	Non-flow.	Slight negative (increasing) trend in salinity & nutrients. Some seasonality in salinity.
Geomorphology	Siltation, bank erosion, trampling, flashier flows.	Roads, harvested forestry areas, bridges and river access by livestock.	Non-flow.	Negative, catchment processes are increasing siltation and bank erosion.
Vegetation	Altered species composition	Alien plant species (high at this site and includes woody perennial species)	Non-flow.	Negative, because the perennial alien plant species present are invasive and will increase if left unchecked, and the proximity to forestry means disturbance will remain high.
	Elevated woody cover and stature.	Forestry.	Non-flow.	
Invertebrates	Instream habitat modification, water quality.	Afforestation, sedimentation.	Non-flow.	Absent, no discernible trends in the data, variable total SASS and ASPT scores.
Fish	Sedimentation of substrates and erosion of banks. Water quality degradation (general turbidity from catchment).	Catchment land use (forestry).	Non-flow.	Negative, ongoing catchment activities negatively affect fish habitat.

The ratings given for EIS are provided in **Table 9.22**. Fish were given a HIGH EIS rating, invertebrates MODERATE and vegetation LOW. Fish and invertebrates were given high scores for the presence of biota that are intolerant to changes in flow and water quality and for high taxon richness. Diversity of fish habitat, refugia for fish and sensitivity of fish habitat to changes in flow were scored high, and fish and invertebrate habitat were both given high scores for sensitivity to changes in water quality.

The overall EIS was **MODERATE**, which would mean the aim would be to maintain the PES. There does not appear to be any obvious opportunities to seek an improvement in the ecological status of this EWR site so this is the recommendation made.

Table 9.22: EIS ratings for 10_Latonyanda

Metrics	PES (2022) Rating				Comments
	Vegetation	Invertebrates	Fish	Median	
Biota (instream and riparian)					
Rare and endangered	0.00		0.00	0.00	VEG: None. FISH: Reference data indicate there may be but none were captured in the samples taken. INVERTS: We do not have the information to assess this.
Unique	1.50		0.00	0.75	VEG: *Combretum erythrophyllum* and *Dietes butcheriana* endemic SnA. FISH: Reference data indicates there may be, but none sampled. INVERTS: We do not have the information to assess this.
Intolerant (flow and/or water quality)	1.00	3.00	4.00	3.00	VEG: Marginal zone sedges & grasses. FISH: Many fish spp flow habitat specialists, many of which occur in fast shallow habitats. INVERTS: Many taxa dependent on flowing water during part/most of their life cycle.
Taxon richness	1.00	3.00	3.00	3.00	VEG: 17 indigenous riparian and wetland species. FISH: Reference data indicates there may be, but surveys showed lesser diversity. INVERTS: 66 taxa under natural conditions and 51 under PES (2022).
Instream and riparian habitats					
Diversity	0.50	2.00	3.00	2.00	VEG: Alluvial woody banks, incised narrow channel, alluvial & bedrock. FISH: High diversity. INVERTS: Instream habitat dominated by cobbles, GSM, and broadleaved marginal vegetation.
Refugia	0.50	2.00	3.00	2.00	VEG: Low. FISH: High level. INVERTS: Moderate refugia available given the composition of the existing instream habitat.
Sensitivity to change in flows	0.50	2.00	3.00	2.00	Veg: Low. FISH: Substrate maintenance is dependent on suitable flows. INVERTS: Some habitat sensitive to flow changes.
Sensitivity to change in water quality	0.00	3.00	3.00	3.00	VEG: None. FISH: Relatively small watercourse and therefore limited buffer capacity to tolerate changes. INVERTS: Some habitat sensitive to water quality related flow changes.
Migration route/corridor	0.50	1.00	2.00	1.00	VEG: Some. FISH: A generally open and longitudinally connected watercourse that would promote migration movements in support of breeding and dispersal. INVERTS: Odonata may use the riparian zone as a corridor for movement.
Importance of conservation and natural areas	1.00	1.00	1.00	1.00	VEG: Some. FISH: Much of the catchment area falls within commercial forestry areas. Although watercourses are generally conserved in principle, the land use tends to be relatively high impact. INVERTS: Within a forestry area.
MEDIAN	0.50	2.00	3.00	2.00	
EIS	LOW	MOD	HIGH	**MOD**	

9.11 11_Mutshindudi

The PES of 11_Mutshindudi is a C category and the river flows close to natural (82% of nMAR). It is situated downstream of Vondo Dam and the Tshinane River tributary, upstream of the confluence with the Luvuvhu River. There are plans to raise and increase water use from Vondo Dam by 2050 that is

expected to significantly reduce flows in the wet season. Low flows in the dry season are expected to remain unchanged as agricultural releases from Vondo Dam are expected to still be met.

The causes and sources of the PES, and projected trends are summarised in **Table 9.23**. Moderate scores for invertebrates, geomorphology, vegetation and fish all were the result of non-flow related issues linked to landuse, the latter three all on negative trajectory.

Table 9.23: Causes and sources of PES, and projected trends at 11_Mutshindudi

Component	Causes	Sources	Flow or non-flow related	Trends
Water quality	Limited data at EWR site. Stable salinity, increase in phosphates.	Urban sprawl upstream of the EWR site.	Non-flow.	Absent, very limited data set.
Geomorphology	Bank erosion due to trampling, siltation of slow flow habitats due to increased fine sediment input.	Widespread agriculture, overgrazing, livestock tracks, rural housing with bare areas around houses, and a moderate density of roads.	Non-flow.	Negative, high pressure at the site due to trampling and bank erosion with siltation in pools and coarser habitats.
Vegetation	Altered species composition.	Alien plant species (high at this site and includes woody perennial species).	Non-flow.	Negative, because the perennial alien plant species present will increase if left unchecked and the site is prone to constant high disturbance from humans and livestock.
Invertebrates	Water quality impacts.	Human settlements	Non-flow.	Absent, no discernible trends present, are variable total SASS and ASPT scores.
Fish	Water quality degradation. Smothering of habitat. Harvesting of riparian vegetation.	Catchment land use (informal/semi-formal residential and agriculture).	Non-flow.	Negative, ongoing habitat changes due to cultivated land surfaces across the catchment.

The ratings given for EIS are provided in **Table 9.24**. Invertebrates and fish were given a HIGH EIS rating because of biota that were intolerant to changes in flow and water quality, high taxon richness of invertebrates, high diversity of habitat that is sensitive to changes in flow for both and water quality for invertebrates, and refugia and a migration corridor for fish. The EIS overall was **MODERATE**, which would mean the aim would be to maintain the PES. Changing well established landuse practices in rural areas is likely to be difficult so the only opportunity for any improvement in ecological status is to remove the exotic woody plants. This will buffer against further degradation in condition because the exotic plants are going to spread if left unchecked. In particular, *Mimosa pigra* is present and is a serious invasive plant that can take over floodplains. This plant can spread from here downstream to the Luvuvhu River Floodplain. Once established it is very expensive and difficult to remove. It must be removed now and checks made to see if it is on the Luvuvhu River Floodplain.

Table 9.24: EIS ratings for 11_Mutshindudi

Metrics	PES (2022) Rating				Comments
	Vegetation	Invertebrates	Fish	Median	
Biota (instream and riparian)					
Rare and endangered	3.50		1.00	2.25	VEG: 3 Nationally protected tree species: *Breonadia salicina, Philenoptera violacea, Sclerocarya birrea* subsp. *Caffra* and *Crinum moorie*. FISH: Reference data indicate there may be but none were captured in the samples taken. INVERTS: We do not have the information to assess this.
Unique	0.00		1.00	0.50	VEG: None. FISH: Reference data indicate there may be but none were captured in the samples taken. INVERTS: We do not have the information to assess this.
Intolerant (flow and/or water quality)	1.00	3.00	4.00	3.00	VEG: Marginal zone sedges & grasses. FISH: Many fish species are flow habitat specialists and prefer fast shallow habitats. INVERTS: Many taxa are dependent on flowing water for part of their life cycles.
Taxon richness	2.00	3.00	2.00	2.00	VEG: There are 27 indigenous riparian and wetland species. FISH: Reference data indicate a high diversity of fish than was seen in the samples collected. INVERTS: There are 67 taxa under natural conditions and 47 under PES (2022).
Instream and riparian habitats					
Diversity	1.50	3.00	3.00	3.00	VEG: Alluvial woody banks, bedrock woody in-channel features, pools, reed beds. FISH: High diversity. INVERTS: Is a cascade present in the upper reach, cobbles, boulders, rapids, riffles and runs, GSM and graminoids.
Refugia	2.00	2.00	3.00	2.00	VEG: Rare & endangered species listed above, especially *B. salicina*. FISH: High level. INVERTS: Moderate refugia available given the composition of the existing instream habitat.
Sensitivity to change in flows	1.50	3.00	3.00	3.00	VEG: Bedrock, rheophytic areas. FISH: Substrate maintenance is dependent on suitable flows. INVERTS: Some habitat sensitive to flow changes, namely the cascade and some sections of rapids.
Sensitivity to change in water quality	0.00	3.00	2.00	2.00	VEG: None. FISH: Relatively larger watercourse and therefore water volume allows for a buffer to tolerate changes. INVERTS: Some habitat sensitive to water quality related flow changes.
Migration route/corridor	1.00	2.00	3.00	2.00	VEG: Fragmented but distinct from upland cultivated areas. FISH: A generally open and longitudinally connected watercourse that would promote migration movements in support of breeding and dispersal. INVERTS: Paleomonidae occur in this river and Odonata may use the riparian zone as a corridor for movement.
Importance of conservation and natural areas	1.00	1.00	1.00	1.00	VEG: Some. FISH: Low - much of the catchment is commercial farmland. INVERTS: Open area present.
MEDIAN	1.25	3.00	2.50	2.00	
EIS	MOD	HIGH	HIGH	**MOD**	

9.12 12_Luvuvhu

The PES of 12_Luvuvhu is a C category and the annual river flows are moderate (62% of nMAR). It is situated downstream of Nandoni Dam and upstream of the confluence with the Mutale River and the

Kruger National Park and flows adjacent to the Mphaphuli Protected Environment. Maintaining low-flows in the Mutale and Luvuvhu Rivers upstream of their confluence is vital to maintain low-flows in the lower Luvuvhu River through the floodplain, and the floods are needed to inundate and maintain the floodplain (see EWR Report - Wetland Assessment (Volume 2): Ecological Water Requirements). Demand from Nanḍoni Dam is expected to increase by 2050 that will result in fewer wet season spills and lower dry season flows because Nanḍoni Dam is not expected to be able to meet all the required releases.

The causes and sources of the PES, and projected trends are summarised in **Table 9.25**. There are flow related causes because of reduction in flow and sediment downstream of Nanḍoni Dam that create poor inchannel habitat conditions and a poor score for geomorphology. Moderate scores were given for vegetation and fish, and these three components are all on a negative trajectory.

Table 9.25: Causes and sources of PES, and projected trends at 12_Luvuvhu

Component	Causes	Sources	Flow or non-flow related	Trends
Water quality	High seasonality in electrical conductivity.	Urban sprawl & urban runoff.	Non-flow.	Slight positive (decreasing) trend in electrical conductivity, slight increasing trends in nutrients.
	Increasing trends in nutrients.	WWTW upstream of EWR site.		
Geomorphology	Reduced bed sediment input with increased fine sediment input; reduced high flows; reed encroachment; bank erosion.	Widespread agriculture, overgrazing, livestock tracks, and rural housing with bare areas around houses; a moderate density of roads increasing fine sediment input; sand mining; trampling.	Non-flow.	Negative, catchment degradation is ongoing with possible growth of bank and bar habitat due to sand mining.
	Reduced bed sediment input, reduced high flows.	Nanḍoni Dam	Flow.	
Vegetation	Altered species composition	Annual and perennial alien plant species.	Non-flow.	Negative, because the perennial alien plant species present are invasive and will increase if left unchecked, and the site is prone to high levels of disturbance from humans and livestock.
	Reduced vegetation cover and abundance.	Vegetation removal/ clearing/ access paths and roads.	Non-flow.	
	Increased reed density and cover	Flow regulation and reduction, flood peak reduction.	Flow.	
Invertebrates	Flow modification.	Downstream of Albasini & Nanḍoni Dams.	Flow.	Absent, there is high variability in the total SASS and ASPT scores.
	Instream habitat modification.	Nutrient enrichment, human settlements.	Non-flow.	
Fish	Sedimentation of substrates. Water quality degradation (general & turbidity).	Catchment land use (formal & informal residential sectors, and commercial sectors).	Non-flow.	Negative, impact of dams ongoing with resultant changes to habitat.

The ratings given for EIS are provided in **Table 9.26**. Vegetation was given a LOW, invertebrates a MODERATE and fish a HIGH rating for EIS. Invertebrates scored high for taxa intolerant to changes in flow and water quality, and sensitivity of invertebrate habitat to changes in flow. Fish scored high

because of fish intolerant to changes in flow and water quality, and for high diversity of habitat that is sensitive to changes in flow and the migration corridor along the river.

Table 9.26: EIS ratings for 12_Luvuvhu

Metrics	PES (2022) Rating				Comments
	Vegetation	Invertebrates	Fish	Median	
Biota (instream and riparian)					
Rare and endangered	1.50		1.00	1.25	VEG: Matumi (*Breonadia salicina*) and Apple Leaf (*Philonoptera violaceae*) are protected national tree species. FISH: Reference data show they may be but none were captured in the samples collected. INVERTS: We do not have the information to assess this.
Unique	0.00		1.00	0.50	VEG: None. FISH: Reference data show they may be but none were captured in the samples collected. INVERTS: We do not have the information to assess this.
Intolerant (flow and/or water quality)	1.00	3.00	4.00	3.00	VEG: Wetland sedges and grasses. FISH: Many fish species are flow habitat specialists that prefer fast shallow habitats. INVERTS: Many taxa are dependent on flowing water for part of their life cycles.
Taxon richness	2.00	3.00	2.00	2.00	VEG: There are 35 indigenous riparian species. FISH: Reference data show higher diversity than was collected in the samples. INVERTS: There are 70 taxa under natural conditions and 52 under PES (2022).
Instream and riparian habitats					
Diversity	2.00	2.00	3.00	2.00	VEG: Pool-riffle/run, reed beds and woody banks, with flood channels. FISH: High diversity. INVERTS: Cobbles, boulders, riffles and runs, GSM and graminoids.
Refugia	0.00	2.00	3.00	2.00	VEG: None. FISH: High level. INVERTS: Moderate refugia available given the composition of the existing instream habitat.
Sensitivity to change in flows	1.00	3.00	3.00	3.00	VEG: Marginal zone species. FISH: Substrate maintenance is dependent on suitable flows. INVERTS: Many invertebrates need water for part of their life cycles.
Sensitivity to change in water quality	1.00	2.00	2.00	2.00	VEG: Potentially to nutrients for e.g. reeds. FISH: Relatively larger watercourse and therefore water volume allows for a buffer to tolerate changes. INVERTS: Some habitat sensitive to water quality related flow changes.
Migration route/corridor	1.00	2.00	3.00	2.00	VEG: Minimal as fragmented. FISH: A generally open and longitudinally connected watercourse that would promote migration movements in support of breeding and dispersal. INVERTS: Paleomonidae occur in this river, Odonata may use the riparian zone as a corridor for movement.
Importance of conservation and natural areas	1.00	1.00	2.00	1.00	VEG: Highly disturbed and developed area. FISH: Mixed land use catchment, including urbanised, private conserved, and conserved. INVERTS: Open areas present.
MEDIAN	1.00	2.00	2.50	2.00	
EIS	LOW	MOD	HIGH	**MOD**	

The overall EIS was **MODERATE**, which would normally mean a target to maintain the PES. With the projected increases in water use planned the only opportunity for improvement is to manage the non-flow related issues and given the importance of this river for the lower Luvuvhu River and Floodplain

every effort should be made. Nutrients in wastewater treatment works releases could be reduced that will have positive knock-on effects for invertebrates and fish. Sand mining could be restricted or better controlled that would improve instream habitats for invertebrates and fish. Clearing exotic woody plants will help improve conditions overall. The outcome of the Future water use is assessed and explained in the EWR Report - River Assessment (Volume 3): Ecological Water Requirements.

9.13 13_Mutale1

The PES of 13_Mutale1 is a C category and the river flows near natural (93% of nMAR). The EWR site is situated downstream of Lake Fundudzi and flows adjacent to the Mphaphuli Protected Environment and through an area where there are many Channeled Valley and Un-channeled Valley Bottom wetlands. There are plans to build Rambuda Dam to meet the projected increases in demand from the Mutale River by 2050 that is going to reduce flow all year round.

The causes and sources of the PES, and projected trends are summarised in **Table 9.27**. Apart from salinity all are non-flow related. The lowest moderate scores were given for geomorphology, invertebrates and fish all for reasons related to landuse, siltation and degraded inchannel habitats. These were expected to continue to degrade on a negative trajectory.

Table 9.27: Causes and sources of PES, and projected trends at 13_Mutale1

Component	Causes	Sources	Flow or non-flow related	Trends
Water quality	Slight increase in salinity but seasonality in data, decreasing nutrients.	Evaporation during low flow periods.	Flow.	Slight negative (increasing) trend in salinity, slight positive (decreasing) trend in nutrients.
Geomorphology	Siltation, bank erosion.	Widespread subsistence farming, roads and bare areas around villages; trampling; overgrazing.	Non-flow.	Negative, catchment degradation is likely to worsen, increasing siltation.
Vegetation	Altered species composition.	Annual and perennial alien plant species.	Non-flow.	Absent, trend considered stable because the alien plant species present were minimal and were annual weeds.
Invertebrates	Instream habitat modification, water quality impacts.	Human settlements.	Non-flow.	Absent, no discernible trends in the data, there was high variability in the total SASS and ASPT scores.
Fish	Water quality degradation (mostly turbidity).	Catchment land use (formal & informal residential sectors, and commercial sectors).	Non-flow.	Negative, following the trends in water quality and geomorphology (habitat).

The ratings given for EIS are provided in **Table 9.28**. Vegetation and fish were given a HIGH EIS rating and invertebrates a MODERATE rating. All scored high for taxon richness and taxa that are intolerant to changes in flow and water quality, and vegetation scored high for rare, endangered and unique plants present. There were high scores for diversity of instream and aquatic habitat that were sensitive to changes in flow, overall.

Table 9.28: EIS ratings for 13_Mutale1

Metrics	PES (2022) Rating				Comments
	Vegetation	Invertebrates	Fish	Median	
Biota (instream and riparian)					
Rare and endangered	3.00		0.00	1.50	VEG: *Crinum macowanii* (Not threatened but population declining). FISH: None were captured in the samples. INVERTS: We do not have the information to assess this.
Unique	3.00		1.00	2.00	VEG: *Combretum erythrophyllum* and *Miscanthus junceus* (SnA endemic), *Schoenoplectus brachyceras* (SA endemic). FISH: Reference data indicate there may be but none were captured in the samples collected. INVERTS: We do not have the information to assess this.
Intolerant (flow and/or water quality)	3.00	3.00	4.00	3.00	VEG: Aquatic zone and pools within seepage wetlands. FISH: Many fish species are flow habitat specialists that prefer fast shallow habitats. INVERTS: Many taxa are dependent on flowing water for part of their life cycle.
Taxon richness	3.00	3.00	3.00	3.00	VEG: There are 36 indigenous riparian and wetland species. FISH: Reference data shows comparable diversity to the samples collected. INVERTS: There are 69 taxa under natural conditions and 49 under PES (2022).
Instream and riparian habitats					
Diversity	3.00	2.00	3.00	3.00	VEG: Bedrock channel, woody banks, flood bench and levee, seepage wetland, aquatic zone, pools and alluvial lateral bars. FISH: High diversity. INVERTS: Bedrock/boulder rapids, runs and graminoids.
Refugia	2.00	2.00	3.00	2.00	VEG: Wetland and aquatic species. FISH: High level. INVERTS: Moderate refugia available given the composition of the existing instream habitat.
Sensitivity to change in flows	2.00	3.00	3.00	3.00	VEG: Aquatic zone and pools within seepage wetlands. FISH: Substrate maintenance is dependent on suitable flows. INVERTS: Some habitat sensitive to flow changes.
Sensitivity to change in water quality	1.50	2.00	2.00	2.00	VEG: Aquatic zone. FISH: Relatively large watercourse and therefore water volume allows for a buffer to tolerate changes. INVERTS: Some habitats are sensitive to water quality related flow changes.
Migration route/corridor	1.00	2.00	3.00	2.00	VEG: Corridor functionality fragmented and deteriorated. FISH: A generally open and longitudinally connected watercourse that would promote migration movements in support of breeding and dispersal. INVERTS: Paleomonidae occur in this river, Odonata may use the riparian zone as a corridor for movement.
Importance of conservation and natural areas	2.00	1.00	2.00	2.00	VEG: High species diversity with riparian, aquatic and wetland habitats. FISH: Mixed land use catchment, including urbanised and conservation areas. INVERTS: Open areas are present.
MEDIAN	2.50	2.00	3.00	2.00	
EIS	HIGH	MOD	HIGH	**MOD**	

The overall EIS was **MODERATE**, which would mean aiming to maintain the PES. However, given the importance of the Mutale River flows as inflows for the lower Luvuvhu River and Floodplain and the extensive wetlands along the river, improving the conditions along the river to buffer against the planned increases in water use is needed. Since all issues were related to the well established landuse practices there are limited opportunites for improvement so the recommendation made was to maintain the status

quo. Perhaps the Future water use plans should be reviewed in light of the importance of this river. The outcome of the Future water use is assessed and explained in the EWR Report - River Assessment (Volume 3): Ecological Water Requirements.

9.14 14_Mutale2

The PES of 14_Mutale2 is a C category and the river flows near natural (93% of nMAR). It is situated in the Kruger National Park just upstream of the confluence with the Limpopo River. There are plans to build Rambuda Dam upstream to meet the projected increases in demand from the Mutale River by 2050 that is going to reduce flow all year round.

The causes and sources of the PES, and projected trends are summarised in **Table 9.29**. Apart from salinity and the gauging weir all are non-flow related. The lowest moderate scores were given for geomorphology, invertebrates and fish all for reasons related to landuse, siltation and degraded inchannel habitats conditions. These were expected to continue to degrade down a negative trajectory.

Table 9.29: Causes and sources of PES, and projected trends at 14_Mutale2

Component	Causes	Sources	Flow or non-flow related	Trends
Water quality	Increasing trend in salinity.	Salinity driven by evaporation.	Flow.	Moderate negative (increasing) trend in salinity & nutrients.
	Slight increase in nutrients.	Localised subsistence farming.	Non-flow.	
Geomorphology	Bank erosion; sedimentation in pools.	Trampling at site; weir; localised subsistence farming, grazing, roads and bare areas around villages in catchment.	Non-flow.	Negative, catchment degradation is likely to increase with more sedimentation at the site.
Vegetation	Altered species composition.	Annual and perennial alien plant species.	Non-flow.	Absent, because the alien plant species found were minimal and mostly annual weeds.
Invertebrates	Water quality.	Potential nutrient enrichment, lodges, settlements.	Non-flow.	Absent, no discernible trends due to high variability in total SASS and ASPT scores.
Fish	Instream barriers.	Gauging weir.	Flow.	Negative, ongoing degradation of fish habitat and the weir is a barrier to migration.

The ratings given for EIS are provided in **Table 9.30**. Invertebrates and fish were given a HIGH EIS rating and vegetation a MODERATE rating. Invertebrates and fish scored high for taxon richness and taxa that are intolerant to changes in flow and water quality, and vegetation scored high for rare, endangered plants present. Fish scored high for habitat diversity and refugia, while invertebrates scored high for habitat that was sensitive to changes in flow. All scored high for being in the Kruger National Park.

The overall EIS was **MODERATE**, which would normally require maintaining the PES. However, given the importance of the Mutale River flows as inflows for the lower Luvuvhu River and Floodplain and the extensive wetlands along the river, improving the conditions along the river to buffer against the planned increases in water use is needed. Since all issues were related to the well established landuse practices

there are limited opportunites for improvement so the recommendation made was to maintain the status quo. Perhaps the Future water use plans should be reviewed in light of the importance of this river. The outcome of the Future water use is assessed and explained in the EWR Report - River Assessment (Volume 3): Ecological Water Requirements.

Table 9.30: EIS ratings for 14_Mutale2

Metrics	PES (2022) Rating				Comments
	Vegetation	Invertebrates	Fish	Median	
Biota (instream and riparian)					
Rare and endangered	3.00		1.00	2.00	VEG: There are 3 protected tree species at the National scale: *Breonadia salicina, Combretum imberbe, Philenoptera violacea*. FISH: Reference data indicate there may be but none were captured in the samples collected. INVERTS: We do not have the information to assess this.
Unique	2.00		1.00	1.50	VEG: *Schotia brachypetala, Senegalia burkei* (SA endemics). FISH: Reference data indicate there may be but none were captured in the samples collected. INVERTS: We do not have the information to assess this.
Intolerant (flow and/or water quality)	1.00	3.00	4.00	3.00	VEG: Marginal zone sedges. FISH: Many fish species are flow habitat specialists that prefer fast shallow habitats. INVERTS: Many taxa are dependent on flowing water for part of their life cycles.
Taxon richness	2.00	3.00	3.00	3.00	VEG: There are 30 indigenous riparian and wetland species. FISH: Reference data and samples collected have comparable diversity. INVERTS: There are 64 taxa under natural conditions and 51 under PES (2022).
Instream and riparian habitats					
Diversity	1.50	2.00	3.00	2.00	VEG: Bedrock channel, woody banks, flood bench flood channel and mixed bedrock / alluvium. FISH: High diversity. INVERTS: Bedrock/boulder rapids, cobbles, runs and graminoids.
Refugia	1.50	2.00	3.00	2.00	VEG: Riparian tree species. FISH: High level. INVERTS: Moderate refugia available given the composition of the existing instream habitat.
Sensitivity to change in flows	0.50	3.00	3.00	3.00	VEG: Low. FISH: Substrate maintenance is dependent on suitable flows. INVERTS: Some habitat sensitive to flow changes.
Sensitivity to change in water quality	0.50	2.00	2.00	2.00	VEG: Low. FISH: Relatively larger watercourse and therefore water volume allows for a buffer to tolerate changes. INVERTS: Some habitats are sensitive to water quality related flow changes.
Migration route/corridor	1.00	2.00	2.00	2.00	VEG: Although tall trees are part of the corridor, it is fragmented and less important. FISH: A generally open and longitudinally connected watercourse that would promote migration movements in support of breeding and dispersal. There is a weir upstream which acts as a barrier to migration. INVERTS: Paleomonidae occur in this river, Odonata may use the riparian zone as a corridor for movement.
Importance of conservation and natural areas	4.00	3.00	4.00	4.00	VEG: KNP. FISH: Catchment area in formally conserved area of national importance. INVERTS: KNP.
MEDIAN	1.50	2.50	3.00	2.00	
EIS	MOD	HIGH	HIGH	**MOD**	

10 SOCIO-ECONOMICS

10.1 Introduction

The main objective of the socio-economics component of the study is to analyse the socio-economic trade-offs involved in water allocation between ecosystems and human uses, and how this might change under various flow regimes, the results of which are then used to inform the selection of the preferred Water Resource Class scenario.

10.1.1 Assumptions and limitations

Note that the socio-economic component was limited to a desktop study, apart from a short reconnaissance site visit to the study area. No primary data were collected. This component of the analysis therefore relies solely on available spatial datasets and existing information published in the literature and available in government published reports, and expert opinion on the relationship to ecological variables.

10.2 EWR sites with a focus on socio-economics

10.2.1 Catchment description

A total of 3.3 million people lived within the study area catchments in 2016 (StepSA 2018). While the total population has increased by some 720 000 people since 1996 (a 28% increase), population growth has slowed over the years. Population density is highest around the main cities and large towns, such as Polokwane, Musina, Makhado, Modimole and Mokopane, and particularly in the dense rural settlement areas of Venda, Lebowa and Ganzankulu. The population is youthful with high birth rates and high dependency ratios. More than one third of the population is considered poor or living in poverty and as a result many households are heavily reliant on natural ecosystems for maintaining livelihoods and food security.

The total GVA for the study area was estimated to be R70.1 billion in 2016. The highest GVA values are found in and around major towns, particularly in the Upper Sand, Upper Luvuvhu and Lower Sand IUAs. GVA is lowest in the Kalkpan se Loop and Kolope IUAs. The main drivers of the economy in the study area are mining and agriculture, and community services (i.e., government employment), followed by trade, retail, wholesale, and financial services. Most of the economic production is focused in and around the main urban centres, areas of mining activity, as well as from the areas where irrigation is practised to produce high value agricultural outputs.
The most important areas of economic activity in the study area as a whole have been identified as follows:

- Urban economies in the South-western (Polokwane, Mokopane, Modimole) and North-eastern (Musina, Makhado) sections of the study area;
- Intensive mining in the South-western areas of the study area, mostly in the Upper Nyl & Sterk IUA, in the North-central areas in the Lower Sand and Kolope IUAs, and in the eastern Lower Luvuvhu IUA;
- Commercial irrigation agriculture along the Limpopo, Sand, Luvuvhu, Lephalala and Nzhelele rivers;
- Commercial timber plantations in the Upper Luvuvhu IUA;

- Widespread dry-land cultivation economy in the western Upper Lephalala, Lower Lephalala, Upper Nyl & Sterk, and Mogalakwena IUAs; and
- Important ecotourism economy that covers large areas of the study area and is associated with national and local protected areas and privately owned game reserves.

People obtain significant benefits from aquatic ecosystems. Ecosystem services are therefore an integral factor influencing the economic and social status of the different parts of the study area. In the study area the benefits include river water for domestic use and watering of crops, harvested wild plant and animal resources from rivers and wetlands for food, energy, medicine and raw materials, and fodder for livestock. Cultural ecosystem services include the contribution of wetlands and rivers to nature-based tourism value, and regulating ecosystem services include carbon retention and flood attenuation benefits. The value of the aquatic ecosystems within the study area is estimated to be in the order of R410 million per year. The nature-based tourism value accounts for just under half of the total value of aquatic ecosystems in the study area. The provisioning services (water for domestic use, harvested wild resources and wetland contribution to livestock production) account for 44% of the total value and therefore make a significant contribution to livelihoods and household income, particularly in areas where economic opportunities are limited.

10.2.2 Data collection and analysis

Information on population, income, livelihoods and living conditions was derived from StatsSA Census data for 1996, 2001 and 2011. Where census data had been disaggregated into mesozones by StepSA (2016, 2018), these were used to obtain summaries at the level of the IUA. This dataset also includes information on demographic, education, poverty, and other socio-economic attributes over time. For other census data, summaries were produced based on data at the slightly larger sub-place (SP) level. The latest (2020) land-use land cover maps were used in conjunction with information on water users in the study area, to create a spatial description of water use. Estimates of gross value added (GVA) and employment per sector per IUA were made for 2016 (StepSA 2018). These were based on the spatial disaggregation of GVA and employment data by mesozone for 2016 from the CSIR StepSA website (StepSA 2018). These figures were based on original data provided by Quantec at the Local Municipality level and disseminated to Mesozone level using the dasymetric map method. Information on water requirements and water use was extracted from the 2017 Reconciliation Strategy for the Limpopo Water Management Area and the Development of a Reconciliation strategy for the Luvuvhu and Letaba Water Supply System, both produced by DWS (DWS 2015, 2017). The extent of agricultural crop production and reared animal production in the study area was assessed based on information collated from the census of commercial agriculture (2017) conducted by Stats SA (Stats SA 2020). Forestry production was estimated based on data collated from Forestry South Africa (Godsmark and Oberholzer 2019). Information on the role of aquatic ecosystems in supporting livelihoods (use of natural resources) was derived from local research studies and Census data. Where information was not available locally, regional estimates were used based on literature from similar social and ecological contexts.

A week-long reconnaissance trip was undertaken in May 2023. The route included all the IUAs of the study area and traversed as many land-use types in each IUA as possible, especially near the rivers. This allowed first hand understanding of the nature of irrigation farming, wildlife ranching and nature-based tourism, and the rural way of life in private and communal land areas.

10.2.3 Description of sites

Socio-economic characteristics of the IUAs are described in detail in an earlier report, and are summarised in Table **10.1**.

Table 10.1: Broad socio-economic description of EWR sites done at the IUA level. Poverty stats and river dependence are 2011, Population and Unemployment are 2016

IUA	EWR sites	Socio-economic description
IUA1: Upper Lephalala 272 000 ha Pop: 16 000 15% poor 0.9% of GVA	1_Lephalala	Relatively sparsely populated with no main towns, and low population growth. There is no tribal land. Few households in this IUA use aquatic ecosystems for their livelihoods. 4% of households depend on river water. Much of the IUA falls within the Waterberg Biosphere Reserve and includes Lapalala Nature Reserve and Matabane Protected Environment. Livestock and game are the dominant land use, with minimal land transformation. Some 10 313 ha are cultivated, of which 7 283 ha is commercial cultivation and 714 ha are irrigated (mainly grains and vegetables, but also some citrus and other fruits). The agriculture sector makes up 9% of the area's GVA. Trade and accommodation contributes 7% and the government sector contributes 31% of GVA.
IUA2: Lower Lephalala 277 000 ha. Pop: 68 000 18% poor 0.7% of GVA	None	The IUA has two small towns and 22% of the area is dense rural settlement, mainly within Lebowa. Population growth rate about 1.4% p.a., 21% unemployment and 18% poor (2011). 3% of households depend on river water. Over 80% remains natural, and 12% is cultivated, half being commercial. 1 603 ha are irrigated (mainly in the north along the Lephalala and Limpopo Rivers), mainly vegetables but also grains and subtropical fruit. Subsistence cultivation is restricted to Lebowa. The agriculture sector contributes 17% of GVA, and there is no other primary sector activity. Trade and accommodation contributes 6%. The economy is highly dependent on the government sector which contributes 76% of GVA.
IUA3: Upper Nyl / Sterk 547 000 ha Pop: 333 000 19% poor 10.8% of GVA	3_Olifantspruit 4_Mogalakwena1	Three major towns are Modimolle (on the Little Nyl River), Mookgophong (close to Nyl River), and Mokopane (on the Mogalakwena River). 15% of the area comprises densely-populated rural settlements. Very few, if any, households depend on river water. About 13% is cultivated, mostly under dryland commercial crops, with 1 985 ha under irrigation, mainly cereals, subtropical fruit, citrus and vegetables. This IUA has the largest share of the study area's commercial cultivation (47%) and area under mining and quarrying (3 321 ha). Livestock and game farming is important in this IUA, accounting for 19% of the total output of reared animal production in the study area. Agriculture contributes 3% of GVA, while mining contributes 8%. The economy is diverse and productive, with Trade and accommodation contributing 30%, and government only 23%.
IUA4: Mogalakwena 1 000 000 ha Pop: 330 000 22% poor 4.9% of GVA	5_Mogalakwena2	No main towns, but several small towns. Almost half of the IUA is densely populated tribal land. The remaining areas are sparsely populated. 4% of households depend on river water. 80% of the land remains natural. Subsistence cultivation (7.7%) is far more extensive than commercial cultivation (2.5%), with 2 483 ha under irrigation (mainly vegetables, maize and citrus). Agriculture makes up 6% of GVA, with mining adding another 1%. The economy is highly dependent on the government sector which contributes 71% of GVA.
IUA5: Kalkpanse Loop 257 500 ha Pop: 3 400 8% poor 0.1% of GVA	2_Rietfontein	This IUA is almost entirely under private ownership and is sparsely populated. 5% of households depend on river water. Most (91.6%) of the land is natural, largely under livestock and game. 5.2% is used for cultivation (5.2%), the majority of which is commercial rain-fed/dryland crops (3.7%). Some 1 011 ha are under irrigation, predominantly vegetables, but also fodder crops. There is no subsistence cultivation or mining. The agriculture sector makes up 63% of GVA. Trade and accommodation makes up 11%, and government 26% of GVA.

IUA	EWR sites	Socio-economic description
IUA6: Upper Sand 494 000 ha Pop: 753 000 20% poor 38.4% of GVA	7_Sand	Includes city of Polokwane. A significant proportion is tribal land. Contains almost 25% of the study area's population. 1% of households depend on river water. Natural cover is relatively low at 58% and supports livestock and game production. Agriculture covers 20% of the area, 10% of which is for commercial and is mainly a mix of pivot irrigated and rain-fed dryland. A total of 6 625 ha are under irrigation, dominated by vegetables (82%), but also large areas of cereals, nuts and subtropical fruits. This IUA accounts for 38% of the study area GVA. Economic activity is relatively diverse. Thus, agriculture and mining account for only 1% each. Trade and accommodation accounts for 24% and government dependence is relatively low at 29%.
IUA7: Lower Sand Pop: 318 000 20% poor 13.6% of GVA	None	Includes Makhado and Musina, and a small proportion is made up of tribal land. Contains almost 10% of the total study area population, concentrated in these areas. The remainder is sparsely populated. 3% of households depend on river water. Mostly under natural cover, including mountainous areas used for recreation and tourism, and a small amount of plantation forestry. 6% under commercial cultivation, which is mostly irrigated, and only 1.7% under subsistence farming. The 10 149 ha under irrigation are evenly dominated by vegetables and nuts. Agriculture and mining contribute 2% and 3% of GVA, respectively. Trade and accommodation contribute 35%, and government dependence is relatively low at 21%.
IUA 8: Mapungubwe 377 000 ha Pop: 15 000 13% poor 0.6% of GVA	6_Kolope	This IUA is sparsely populated, with people concentrated along the Limpopo River. 12% of households depend on river water. Mostly under natural land (91.6%), only 3.2% is used for commercial cultivation, mostly along the Limpopo River. No subsistence cultivation. Some 6 902 ha are under irrigation, of which 72% of citrus, and the rest is mainly vegetables (tomatoes) and cereals or fodder crops. The IUA includes Mapungubwe National Park, Vhembe Nature Reserve and the large Venetia Diamond Mine. The agriculture and mining sectors contribute 10% and 31% of GVA. Trade and accommodation contribute 19%, government dependence is relatively low at 20%.
IUA9: Nzhelele / Ṅwaneḍi 423 000 ha Pop: 224 000 21% poor 3.8% of GVA	8_Nzhelele 9_Ṅwaneḍi	Includes some outskirts of Makhado. Dense rural settlements make up about half of the IUA. 8% of households depend on river water. About 86% of land area is natural. Some 3% of land is used for commercial cultivation, along the Nzhelele and Ṅwaneḍi Rivers and 2.3% is under subsistence cultivation. Of the 5 497 ha under irrigation, most (86%) is citrus, with the remainder dominated by subtropical fruit (avocados) and vegetables. The area includes about 4 980 ha of plantation forests (15% of study area). Agriculture and mining contribute 14% and 1% of GVA, respectively. Trade and accommodation contribute 8%, and there his high dependence on government, which contributes 61% of GVA.
IUA 10: Upper Luvuvhu 226 000 ha Pop: 749 000 21% poor 20.3% of GVA	10-Latonyanda 11_Mutshundudi 12_Luvuvhu	Also includes some outskirts of Makhado. Densely populated IUA containing 28% of study area population. Density is greatest in the tribal lands, which cover a large proportion of the IUA. Unemployment is particularly high, and 37%.4% of households depend on river water. Less than half under natural cover (48%). Commercial cultivation and plantation forestry make up 15% and 9%, respectively. Almost all commercial cultivation is permanent orchards (7%) and irrigated crops (7%). Almost 20 000 ha are under plantation, which is 59% of plantation area the study area. The agriculture sector makes up 3% of GVA, while the contribution from mining is negligible. 59% is forestry. Trade and accommodation make up 27%. Dependence on the government sector is moderate at 38%.

IUA	EWR sites	Socio-economic description
IUA11: Lower Luvuvhu / Mutale 384 000 ha Pop: 299 000 26% poor 4.5% of GVA	13_Mutale1 14_Mutale2	Includes the Pafuri region of Kruger National Park (KNP). Outside KNP, the area lies mostly in Venda. Some 41% of people are unemployed. 14% of households depend on river water. About 86% of land is natural and much of this is under conservation and tourism use, including areas outside KNP, 3.7% is used for subsistence farming and 0.5% is under commercial cultivation. Only 91 ha are under irrigation, almost all subtropical fruit (avocados), but also some citrus. The area contains about 3 560 ha of plantation forests (11% of study area). The agriculture and mining sectors contribute 4% and 7% of GVA, respectively. Trade and accommodation contribute only 4%. The economy is highly dependent on the government sector which contributes 73% of GVA.
IUA12: Shingwedzi 530 000 ha Pop: 228 000 27% poor 3% of GVA	None	Part of the IUA is in KNP. About 22% is tribal land (Venda). Some 40% of people are unemployed. About 0.6% of households depend on rivers for their water supply. This IUA is almost entirely natural (95%). There is very little agriculture and no mining. The 46 ha of land under irrigation is almost entirely under nuts, with a small area under avocados and vegetables. The agriculture sector contributes 2% of GVA. Trade and accommodation contribute 11%. The economy fairly diverse but is still highly dependent on the government sector which contributes 61% of GVA.

10.3 Socio-economic indicators

The socio-economic indicators are summarised in **Table 10.2**.

Table 10.2: Socio-economic indicators and reasons for their selection

		EWR sites													
Indicator	Reasons for selection	1_Lephalala	2_Rietfontein	3_Olifantspruit	4_Mogalakwena1	5_Mogalakwena2	6_Kolope	7_Sand	8_Nzhelele	9_Ṅwaneḍi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale1	14_Mutale2
Local recreational and cultural value	Freshwater ecosystems are important for religious, spiritual, and social cohesion experiences.														
Nature-based tourism value	Nature-based tourism is important and valuable. Rivers and wetlands make a significant contribution to recreational and tourism appeal.														
Fisheries value	Wild fish are harvested on a subsistence basis for consumption and for sale. Important for household food security and household income.														
Plant resource value	Wetland plant resources (reeds, sedges) harvested on a subsistence basis for														

		EWR sites													
Indicator	Reasons for selection	1_Lephalala	2_Rietfontein	3_Olifantspruit	4_Mogalakwena1	5_Mogalakwena2	6_Kolope	7_Sand	8_Nzhelele	9_Ṅwanedi	10_Latonyanda	11_Mutshindudi	12_Luvuvhu	13_Mutale1	14_Mutale2
	construction, mats and baskets.														
Household water benefits	Many households do not have access to a piped water supply or a borehole and rely heavily on rivers and wetlands for their daily water needs (drinking, bathing, washing clothes and watering garden crops).														
Subsistence livestock grazing	Wetlands are a source of floodplain vegetation for cattle to graze. This can make an important contribution to livestock production.														
Carbon retention value	Riverine and wetland habitats make an important contribution to the amelioration of climate change damages through sequestration of carbon.														
Water treatment costs	Poor water quality has an impact on water treatment costs for domestic use.														
Health risk	Poor water quality can have significant human health impacts.														

10.3.1 Nature-based tourism value

Rivers and groundwater-dependent ecosystems all make up an integral part of natural landscapes that are valued for their various experiential opportunities such as recreation, tourism, cultural and religious ceremonies, and for the non-use value associated with the existence of healthy plant and wildlife populations and biodiversity in general. The condition of ecosystems has an influence on nature-based tourism value, local experiential (recreation and other) value, and property value. Collectively, these values are classified as “cultural ecosystem services” (Millennium Ecosystem Assessment 2003). Cultural values are linked to ecosystem integrity which reflects on the quality of biodiversity. Aquatic ecosystem integrity is linked to overall physical and biological health of the system. In this study, we focus on tourism only, due to lack of information on other types of use value.

Tourism is an integral and significant part of the Limpopo economy. Most of the tourism activities in the Limpopo WMA are linked to natural environments, in which aquatic ecosystems are a significant feature for attracting tourists. Thus, choices regarding water allocation and RQOs may impact on the value of

tourism in the study area, with knock-on effects within and beyond this area. The types of tourism and recreation that are potentially affected include recreational freshwater angling, through impacts on fish stocks; and general nature-based tourism, through impacts on landscapes, biodiversity, water levels for swimming, and suitability for human recreational contact.

In this study we estimate the contribution of aquatic ecosystems to tourism value in monetary terms, with changes in value described based on the expected level of sensitivity of nature-based tourism to ecosystem integrity. This incorporates the role of rivers in supporting wildlife densities (see Turpie and Joubert 2001).

The reasons for, and relationship between, indicators linked to tourism value are summarised in **Table 10.3.**

Table 10.3: The reasons for, and relationship between, indicators linked to tourism value

Linked indicator	Reasons	Relationship
Aquatic ecosystem integrity	Nature-based tourism value is tightly linked to ecosystem integrity and quality of biodiversity.	Better aquatic ecosystem integrity = higher nature-based tourism value.

10.3.2 Local recreational and other cultural value

Rivers and groundwater-dependent ecosystems all make up an integral part of natural landscapes that are valued for their various experiential opportunities such as recreation, tourism, and cultural and religious ceremonies. The condition of ecosystems, especially water quality, has an influence on local use value. Aquatic ecosystem integrity is linked to overall physical and biological health of the system.

The contribution of aquatic ecosystems to local recreational and other cultural value was estimated in qualitative terms, with changes in an index described based on the expected level of sensitivity of these activities to ecosystem integrity and water quality. The value of local recreation is unknown but likely to be high where humans are concentrated. Relative expected changes in this value are represented using a scoring system.

The reasons for, a relationship between, indicators linked to local recreation and cultural value are summarised in **Table 10.4**.

Table 10.4: The reasons for, and relationship between, indicators linked to local recreational and cultural value

Linked indicator	Reasons	Relationship
Aquatic ecosystem integrity	Local recreation and cultural values are tightly linked to ecosystem integrity and water quality	Better aquatic ecosystem integrity and water quality = higher local recreational and cultural value.
Water quality		

10.3.3 Fisheries and plant resource value

Rivers and wetlands provide numerous resources which can be harvested, including raw materials such as reeds, fish, and wild plant foods and medicines (Adekola et al. 2008; Jogo & Hassan 2010). The delivery of these ecosystem goods is a function of the productivity of the aquatic ecosystem. The value of this service depends on the extent to which it is demanded, which can be influenced by regulation, as in the case of protected areas. Rural and peri-urban communities harvest a wide range of resources from rivers and wetlands in the study area. Floodplains are particularly important for fish, as are rivers and dams in the study area, and wetlands are important for reeds and sedges. For this study, changes in the capacity to deliver this service will be estimated based on expert opinion on change in abundance of fish and plant populations that result from a change in flows and Ecological condition, i.e., the proportional change in the size of populations with a change in ecological condition.
The reasons for, and relationship between, indicators linked to fisheries value are summarised in **Table 10.5** and plant resource value in **Table 10.6**.

Table 10.5: The reasons for, and relationship between, indicators linked to fisheries value

Linked indicator	Reasons	Relationship
Fish abundance	The value of the fish resource is directly linked to the abundance of fish stocks.	Higher fish abundance = higher fisheries value.

Table 10.6: The reasons for, and relationship between, indicators linked to plant resource value

Linked indicator	Reasons	Relationship
Abundance of reeds and sedges	The value of the plant resource is directly linked to the abundance of plant material that is harvested.	More reeds, sedges and riparian trees = higher plant resource value.
Abundance of riparian trees		

10.3.4 Household water benefits

In the study area there are several households that rely on rivers, wetlands or springs as their main domestic water source for drinking water, bathing, washing clothes and watering crop gardens. Households without access to a piped water supply are reliant on rivers and streams year-round for water. If flows decline during the dry season and cannot meet local demand, households incur a cost by walking further in search of water or have to purchase water from an informal vendor. Channel depth also affects how easily people can get water from rivers using buckets.

Table 10.7: The reasons for, and relationship between, indicators linked to household water benefits

Linked indicator	Reasons	Relationship
Dry average daily volume	The daily benefit of instream water is dependent on dry season flows and the ability to access water.	Lower volumes in the dry season = lower household water benefits.
Average of max depth (dry season)		A deeper channel = lower household water benefits.

10.3.5 Livestock grazing

Farmers utilise wetland and floodplain areas for grazing livestock, these areas provide fodder year-round. Changes in flows and the loss of floods on floodplains in particular have a significant impact on these grazing areas. Reductions in livestock numbers due to the loss of floodplain grazing areas would impact household income and household food security. For this study, changes in the capacity to deliver this service will be estimated based on expert opinion on change in extent of wetland grazing areas that result from a change in flows and Ecological condition and the associated changes in livestock carrying capacity.

The reasons for, and relationship between, indicators linked to livestock grazing are summarised in **Table 10.8**.

Table 10.8: The reasons for, and relationship between, indicators linked to livestock grazing

Linked indicator	Reasons	Relationship
Extent of wetland floodplain grazing area (Extent of floodbenches)	Floodbenches are inundated by the 1:2-year floods, and are where sedges, reeds and riparian shrubs grow.	More floodbenches = more livestock grazing.

10.3.6 Carbon retention value

Large riparian trees play an important role in carbon storage and sequestration. Reduced flows and groundwater levels could cause die back that will change the capacity to deliver this service. This was estimated based on expert opinion of how riparian vegetation changes under different flow regimes and Ecological condition categories, and then assuming a proportional change in the carbon storage value.

The reasons for, and relationship between, indicators linked to carbon-retention value are summarised in **Table 10.9.**

Table 10.9: The reasons for, and relationship between, indicators linked to carbon retention value

Linked indicator	Reasons	Relationship
Abundance of riparian trees	Riparian trees play an important role in carbon storage and sequestration.	More riparian trees = higher carbon retention value.

10.3.7 Urban water supply costs

Poor water quality has a negative impact on water treatment costs. The more polluted the water is, the higher the treatment cost, as more chemicals and treatment processes are needed to treat the water to potable standards. Increased human activity often leads to increased levels of nutrients, pathogens and sediments in rivers and reservoirs, which reduces reservoir capacity and water quality, and downstream users. Higher turbidity and nutrient (phosphorous and nitrogen) levels are strongly correlated with higher total production costs (examples include Kroeger et al. 2019; Letley et al. 2022; TNC 2015). Chemicals used to treat water include hypochlorite, chlorine, sulphur dioxide, aluminium sulphate (or alum) and lime.

The reasons for, and relationship between indicators linked to urban water supply costs are summarised in **Table 10.10**.

Table 10.10: The reasons for, and relationship between, indicators linked to urban water supply costs

Linked indicator	Reasons	Relationship
Nutrients status (or algal biomass)	The level of nutrients and turbidity at municipal water treatment plants is directly correlated with treatment costs.	Higher nutrient and turbidity levels = higher urban water supply costs.
Turbidity		

10.3.8 Health risk

Runoff from agriculture, mining and industry pollutes freshwater ecosystems (pesticides, fertilizers and organic farm wastes; chemicals and heavy metals). Exposure to high levels of these can be toxic and cause serious illness or disease. Poor sanitation and wastewater discharges also pollute river water causing high levels of E.coli and coliforms, which can cause illness such as diarrhoea and vomiting. The levels of these pollutants are influenced by the timing and quantity of flows in a system. Lower flows could lead to less dilution and higher health risks.

The reasons for, and relationship between, indicators linked to health risks are summarised in **Table 10.11.**

Table 10.11: The reasons for, and relationship between, indicators linked to health risks

Linked indicator	Reasons	Relationship
Heavy metals	Agricultural, mining and industrial activities can lead to heavy metal pollution.	Higher concentration of heavy metals = higher health risks.
Biocides, agrichemicals	The use of biocides and agrichemicals in commercial agriculture is extensive.	Higher concentrations of biocides and agrichemicals = higher health risks.
E.coli, total coliforms	*E. coli* and coliform bacteria make drinking water unsafe, causing disease and ill health.	Higher levels of *E.coli* and total coliforms = higher health risks.

10.4 Status and trends

The demand for and use of natural ecosystems and the goods and services that they provide are driven by various factors, including population growth, population density[6], economic growth, rates of urbanisation and commercialisation, land ownership, changes in technologies and access to alternatives, access to services, wealth, and levels of poverty. While the population of South Africa has grown exponentially since 1900 (see Figure 10.1), the population has also urbanised (Figure 10.2) with significant movement of people into cities since the mid-1990s (post-apartheid). In 1960 the rural population represented 60% of the total population but in 2020 this had declined to be closer to 30% and is forecast to decline further to just 20% in 2050 (Figure 10.2). As more people move into cities and alternatives become available (e.g., corrugated iron roofing versus thatch grass), dependence on certain natural resources declines. However, in rural areas where poverty levels remain high and access to economic opportunities is low, reliance on natural resources will persist.

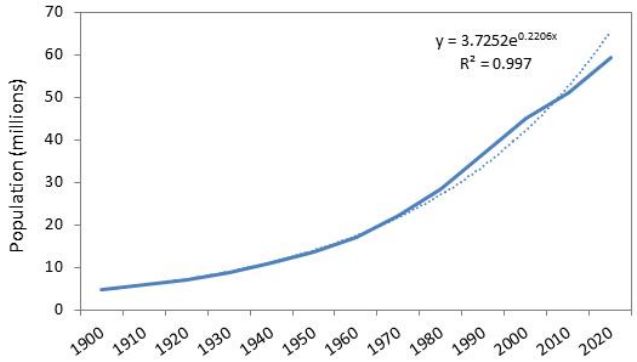


Figure 10.1: South African population from 1900 to 2022. (Source: Statista, 2023; World Bank, 2023a).

[6] The relative density of the population would have changed notably post-1950 due to the implementation of the Group Areas Act of 1950. However, there is no detailed information on population density over this period.

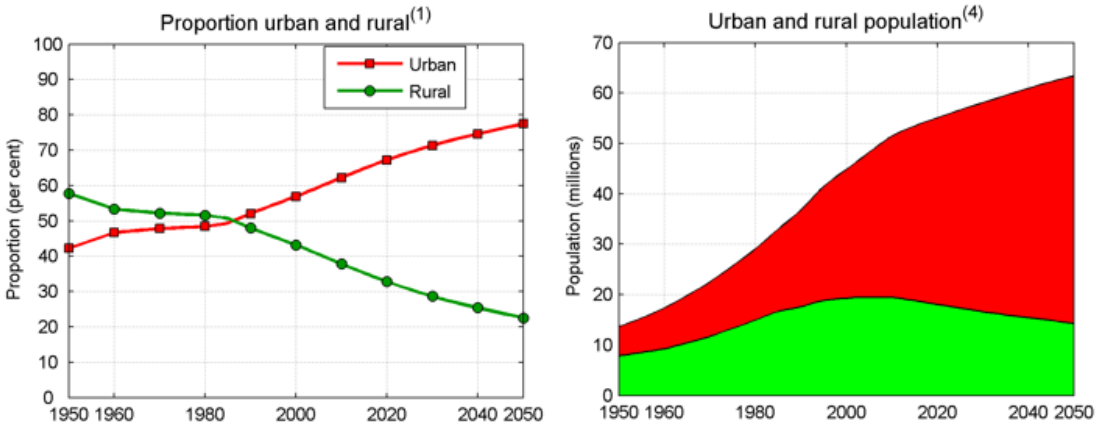


Figure 10.2: Urbanisation in South Africa. (Source: United Nations, https://businesstech.co.za/).

In this section, the anthropogenic drivers of indicator status and associated trends over time are presented for each socioeconomic indicator. The percentages presented are high-level estimates based on expert opinion with the direction of change (either an increase or decrease) relative to PES (2022).

10.4.1 Nature based tourism value

Nature-based tourism is relevant to all EWR sites (all IUAs) across the study area. However, it is highest at EWR sites 1, 3, 6, 12, 13 and 14 that are situated in or close to nature reserves, biosphere reserves or national parks which are important tourist attractions and where tourist routes and facilities exist. The number of international visitors to South Africa started to increase post-apartheid and has risen steadily since the early 2000s **(Figure 10.3**). Prior to 1995, tourism was restricted to the domestic population and was relatively minor, also increasing steeply post-apartheid, as seen by the growth in domestic visitors to the Kruger National Park between 2000 and 2015 (**Figure 10.4**). The Mapungubwe National Park was only gazetted in 1995 but has also seen an increase in total visitor numbers since the early 2000s. In 2010, annual visitor numbers to the park were just 7% of what they are today (SANParks 2021).

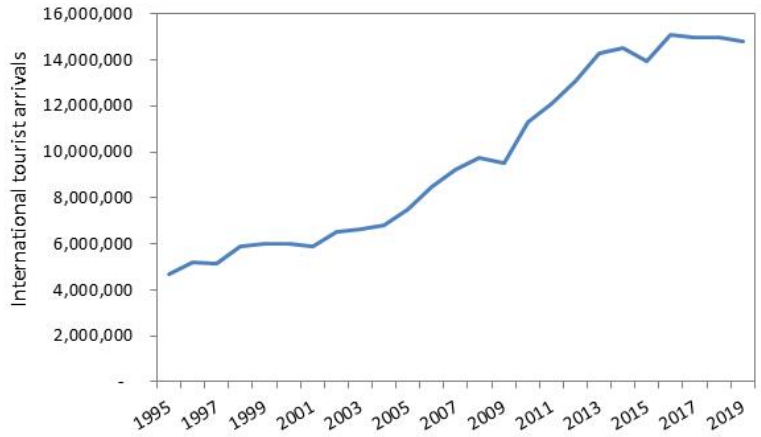


Figure 10.3: International tourist arrivals to South Africa 1995-2019. (Source: World Bank, 2023b).

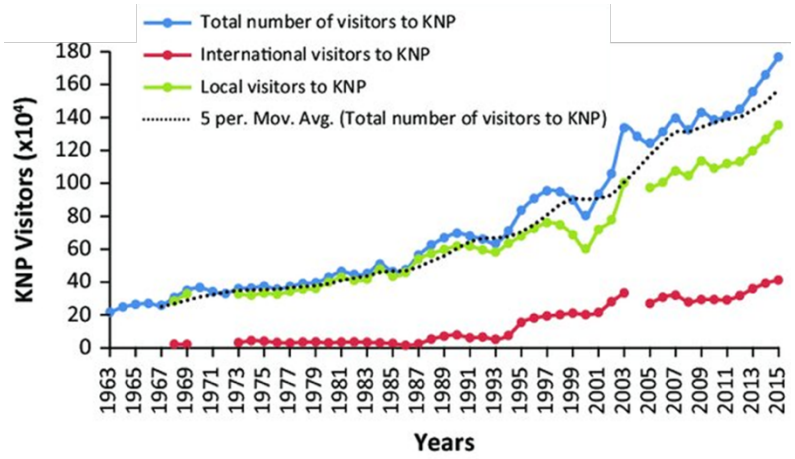


Figure 10.4: Visitor numbers to the Kruger National Park 1963-2015. (Source: Mathivha et al. 2017).

Over the past two decades there has been rapid growth in nature-based tourism (Balmford et al. 2009), emerging as a robust driver of growth for emerging economies. In rural areas, nature-based tourism provides economic possibilities and alternative livelihood strategies for local people. However, tourism can be volatile, driven by external factors operating at local, regional and global scales. For example, an increase in criminal activity and declines in visitor safety can have a significant negative impact on visitation rates and global pandemics such as COVID-19 can completely devastate the tourism industry. However, the industry is also resilient and can bounce back relatively quickly after major shocks. The main drivers of the nature-based tourism indicator status are:

- Local, national, regional and global safety
- Population growth
- Economic growth and prosperity
- Economic stability
- Land transformation (loss of natural habitats and species)
- Transportation, accessibility and infrastructure
- Pollution
- Climate change.

Assuming the 2022 nature-based tourism value was 100%, we have assumed that the value in:

- *c*. 1900 was <1% at EWR sites 1-14, because the population was small, travel was limited, there was no tourism infrastructure or access.
- *c*. 1960 was 10% at EWR sites 1-14, because tourism was limited as a result of the political unrest and the difficulty in creating a highly functioning tourism industry. International visitors were minimal, some domestic travel to nature reserves and national parks.
- *c.* 2000 was 40% at EWR sites 1-14, based on visitor numbers to South Africa and Kruger National Park between 2000 and PES (2022).

10.4.2 Local recreation and cultural values

Freshwater ecosystems are important for local recreation and cultural values, such as being used for cultural and religious ceremonies. Much like nature-based tourism, local recreation has increased over time with economic and population growth. However, the use of freshwater ecosystems for cultural and

religious ceremonies may have decreased in frequency and magnitude as more and more people have moved to the cities and customary beliefs have been slowly eroded. Local recreation and cultural values are relevant at all EWR sites (all IUAs) across the study area. The main drivers of local recreation and other cultural value indicator status are:

- Local safety
- Economic growth and prosperity
- Economic stability
- Urbanisation and commercialisation
- Land transformation (loss of natural habitats and species)
- Transportation, accessibility and infrastructure
- Pollution
- Climate change.

Assuming the 2022 local recreation and other cultural value was 100%, we have assumed that the value in:

- *c.* 1900 was 40% at EWR sites 1-14, due to a smaller population in 1900, very little recreation, but some cultural values being important.
- *c.* 1960 was 60% at EWR sites 1-14, because population has grown since 1900 along with recreational activities and opportunities.
- *c.* 2000 was 90% at EWR sites 1-14, because population and the economy has grown since 1960 so there are more opportunities for recreational activities. However, there was also a small rural population, higher urbanization and eroding of customary beliefs that lead to not much change between 2000 and PES (2022) in terms of these cultural values.

10.4.3 Fisheries value

Subsistence fishing is not a prominent activity in the Limpopo WMA but there is some in the North-eastern parts. It is not relevant at EWR sites 2 or 6. The demand for fish and the amount harvested per household has decreased over time (was higher in 1900), with urbanisation and access to other food sources. However, the population has grown significantly so the number of households harvesting overall has likely increased leading to higher values now that in the past. The main drivers of fisheries value indicator status are:

- Availability/abundance of freshwater fish
- Population growth
- Urbanisation
- Economic growth and prosperity (access to alternatives)
- Poverty
- Transportation, accessibility and infrastructure
- Land transformation (loss of natural habitats and species).

Assuming the 2022 fisheries value was 100%, we have assumed that the value in:

- *c.* 1900 was 15% at EWR sites 1, 3-5 and 7-14, because while more fish were being harvested per household (ratio of 1.4), the population was significantly smaller (about 10% of PES (2022)), which results in an overall decline in fisheries value compared to PES (2022) (1.4 x 0.1 = 0.15).

- *c.* 1960 was 40% at EWR sites 1, 3-5 and 7-14, because while more fish were being harvested per household (ratio of 1.3), the population was smaller (about 30% of PES (2022)), which results in an overall decline in fisheries value compared to PES (2022) (1.3 x 0.3 = 0.40).
- *c.* 2000 was 90% at EWR sites 1, 3-5 and 7-14, because it is likely that slightly more fish were being harvested by households compared to PES (2022) (ratio 1.1) but still a smaller population (about 80% of PES (2022)), leading to a slight decline in overall value compared to PES (2022) (1.1 x 0.8 = 0.9).

10.4.4 Plant resource value

Plants associated with wetlands and riparian areas are harvested for use in construction of traditional homesteads (e.g., sleeping mats, roofs, doors and fences, etc.) and in craft making (e.g., baskets etc.). Plant resource value is not relevant at EWR sites 1-4 nor 6-7. Harvesting of plant resources has been an important activity in the North-eastern rural parts of study area where traditional homesteads are still found. However, the use of plant material in construction has declined in recent times, with access to alternatives such as corrugated iron sheeting and bricks, becoming easier and more affordable to acquire. The rate of urbanisation has also had an impact on natural resource use as there are fewer rural households demanding these resources. The main drivers of plant resource value indicator status are:

- Availability/abundance of aquatic plants such as reeds and sedges
- Population growth
- Urbanisation
- Economic growth and prosperity (access to alternatives)
- Poverty
- Transportation, accessibility and infrastructure
- Land transformation (loss of natural habitats and species).

Assuming the 2022 plant resource value was 100%, we have assumed that the value in:

- *c.* 1900 was 30% at EWR sites 5 and 8-14, because significantly more plant material was being harvested per household (3 times as much) but there was a smaller population (10% of PES (2022)), so the overall use was lower compared to PES (2022) (3 x 0.1 = 0.3).
- *c.* 1960 was 90% at EWR sites 5 and 8-14, because significantly more plant material was being harvested per household (3 times as much) but there was a smaller population (30% of PES (2022)), so the overall use was slightly lower compared to PES (2022) (3 x 0.3 = 0.9).
- *c.* 2000 was 120% at EWR sites 5 and 8-14, because slightly more plant material was being harvested per household (but less than in 1960) due to urbanisation and access to alternatives, and the population was just 80% of PES (2022) so the overall use was 20% higher in 2000 than in 2022, i.e., there has been a decline in the use and value of plant resources in the study area over the past two decades.

10.4.5 Household water benefits

The number of households relying on instream water for household use has declined over time as state water and sanitation services have expanded into rural areas. Not all households have access to piped water in their homes, most have access to taps either in their yards or at communal water stands. As a result, far fewer households rely on rivers for their main source of drinking water. In the most remote

areas of the catchment, there are still households that do rely on rivers. Household instream water usage is relevant at all EWR sites (all IUAs) except for EWR sites 2 and 6, and is highest in the Nzhelele/Ṅwaneḓi, Upper Luvuvhu, and Lower Luvuvhu/Mutale IUAs (EWR sites 8-14). The main drivers of indicator status are:

- Availability of river and stream flows (especially during the dry season)
- Population growth
- Urbanisation
- Economic growth and prosperity (access to alternatives)
- Poverty
- Transportation, accessibility and infrastructure.

Assuming the 2022 household water benefit was 100%, we have assumed that the value in:

- *c.* 1900 was 200% at EWR sites 1, 3-5 and 7-14, because while the population was smaller (10% of PES (2022)) all the households would have been reliant on rivers for their water (100% versus just 5% of households in 2022), collecting the same amount of water as is collected now.
- *c.* 1960 was 420% at EWR sites 1, 3-5 and 7-14, because while the population was smaller (30% of PES (2022)) the majority of the households would still have been reliant on rivers for their water (70% versus just 5% of households in 2022), collecting the same amount of water as is collected now.
- *c.* 2000 was 160% at EWR sites 1, 3-5 and 7-14, because while the population was slightly smaller (80% of PES (2022)) there were households reliant on rivers for their water compared to PES (2022) (10% versus 5% of households in 2022), collecting the same amount of water as is collected now.

10.4.6 Livestock grazing

Farmers rely on riparian and wetland vegetation for grazing livestock, especially during the dry season or in rangeland areas that have been extensively overgrazed/degraded. Rural livestock farmers generally do not have access to supplementary feed. Subsistence livestock grazing is not relevant at EWR sites 2-3 or sites 6-7. Historically, there would have been fewer livestock (fewer people) but there would have been a lower demand for riparian vegetation as a source of grazing due to the rangelands being in a better condition and not overgrazed. However, the literature suggests that between 1940 and 1960 the cattle population remained static at around 12 million animals (Haylet 1968). As the human population grew post-1960 so did the livestock population until a decline in land condition (the result of poor management exacerbated by climate change) caused a decline in livestock numbers over the past two decades (Maluleke & Mokwena 2017; **Figure 10.5**). Cattle numbers in Limpopo declined by 9% (from 14 million to 12.8 million) between 1996 and 2018, aligning with numbers recorded in the 1960s. The condition of rangelands and riparian vegetation has declined under PES (2022). The main drivers of indicator status are:

- Condition of grazing land
- Access to grazing land
- Stock theft
- Population growth
- Urbanisation
- Economic growth and prosperity

- Climate change
- Poverty
- Transportation, accessibility and infrastructure.

Assuming the 2022 value of livestock grazing was 100%, we have assumed that the value in:

- *c.* 1900 was 80% at EWR sites 1, 4-5 and 8-14, because there were fewer livestock, and the rangelands were in better condition and able to adequately support this number of animals.
- *c.* 1960 was 100% at EWR sites 1, 4-5 and 8-14, because there were the same number of livestock with reliance on riparian and wetland vegetation as a source of feed.
- *c.* 2000 was 125% at EWR sites 1, 4-5 and 8-14, because there were more livestock with a heavy reliance on riparian and wetland vegetation as a source of feed.

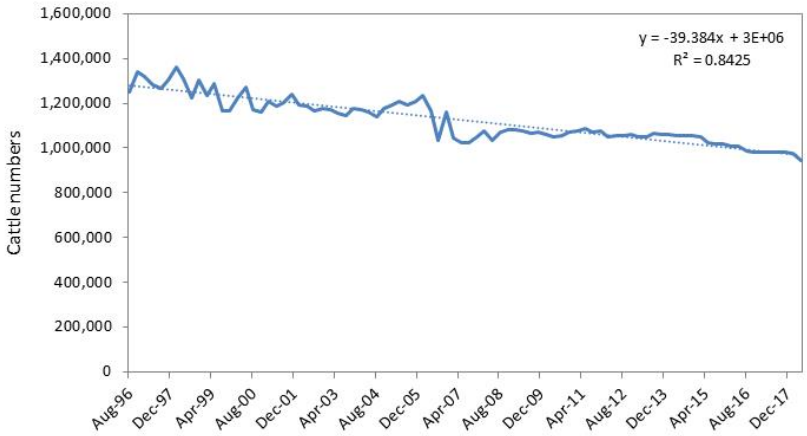


Figure 10.5: Cattle numbers in Limpopo from 1996-2018. Source: DAFF quarterly livestock statistics.

10.4.7 Carbon retention value

Riparian trees play an important role in carbon storage and sequestration. This is relevant at all EWR sites (all IUAs). Over time, population and economic growth has fuelled an increase in urban areas, mining activities and agricultural land leading to the degradation and loss of natural habitats. The clearing of riparian vegetation for cultivated fields is common with significant amounts of natural habitat lost to agricultural fields (both commercial and subsistence). Clearing of trees for wood is also common at most sites. A loss in woody biomass leads to a loss in carbon storage and the values associated with retaining the carbon. The main drivers of indicator status are:

- Land transformation (urbanisation, agriculture, mining)
- Population growth
- Economic growth and prosperity
- Climate change
- Poverty
- Transportation, accessibility and infrastructure.

Assuming the 2022 value of carbon retention was 100%, we have assumed that the value in:

- *c.* 1900 was:

    - 130% at EWR sites 2 and 14 because these sites were in a relatively good condition and have not lost large amounts of vegetation.
    - 150% at EWR sites 1, 3-13 because these sites were in a worse condition due to vegetation loss through trampling (cattle and wildlife) and clearing for wood and for cultivation.
- *c.* 1960 was:
    - 120% at EFlows zones 2 and 14 because some vegetation loss with agricultural expansion, but still 20% more than PES (2022).
    - 140% at EFlows zones 1, 3-13 because some vegetation loss with agricultural expansion, but still 40% more than PES (2022).
- *c.* 2000 was:
    - 105% at EWR sites 2 and 14, further loss but still slightly more than the PES (2022).
    - 120% at EWR sites 1, 3-13, further loss but still slightly more than the PES (2022).

10.4.8 Urban water supply costs

Urban water supply costs increase when volumes for treatment increase and when the quality of water for treatment deteriorates requiring the use of more expensive chemicals and processes for treatment. This is relevant at all EWR sites (all IUAs) except for sites 2 and 6. Over time as the population has grown the amount of water being treated for reticulation has also increased to meet these growing demands. At the same time, the cost of treating $1m^3$ of water has increased due to declining water quality from urban expansion, increasing and intensified agricultural production and growth in mining activities. Pollution (e.g., fertilisers, heavy metals) runs off into rivers and streams that leads to higher chemical usage at treatment plants to treat the water to potable drinking standards. The main drivers of indicator status are:

- Land transformation (urbanisation, agriculture, mining)
- Population growth
- Economic growth and prosperity
- Climate change
- Transportation, accessibility and infrastructure.

Assuming the 2022 urban water supply cost is 100%, we have assumed that the cost in:

- *c.* 1900 was 10% at EWR sites 1, 3-5 and 7-14 prior to mining and commercial agriculture with a smaller population (10% of PES (2022)) results in costs that are less than 10% of PES (2022).
- *c.* 1960 was 30% at EWR sites 1, 3-5 and 7-14 because of some growth in the population and some agricultural and mining expansion.
- *c.* 2000 was 80% at EWR sites 1, 3-5 and 7-14 because of significant growth in the population, rapid expansion of agriculture and mining post-1994.

10.4.9 Health risk

Health risk has increased over time as the population has grown and the economy has developed with increased wastewater return flows, expansion in agriculture and mining leading to higher levels of fertiliser use and increased irrigation return flows as well as higher levels of biocides. The presence of *E.coli*, nutrients and heavy metals in water can lead to increasing health risk, especially in areas where households are reliant on rivers as their main source of drinking water. This is relevant to all EWR sites (all IUAs) except sites 2 and 6. Health risk has increased over time. The main drivers of indicator status are:

- Land transformation (urbanisation, agriculture, mining)
- Population growth
- Economic growth and prosperity
- Climate change
- Poverty.

Assuming the 2022 health risk is 100%, we have assumed that the risk in:

- *c.* 1900 was 10% at EWR sites 1, 3-5 and 7-14 prior to mining and commercial agriculture with a smaller population (10% of PES (2022)) results in risks that are less than 10% of PES (2022).
- *c.* 1960 was 30% at EWR sites 1, 3-5 and 7-14 because of some growth in the population and some agricultural and mining expansion.
- *c.* 2000 was 80% at EWR sites 1, 3-5 and 7-14 because of significant growth in the population, rapid expansion of urban areas, wastewater return flows, agriculture and mining post-1994. Risks 20% less than PES (2022).

11 REFERENCES

Adekola, O., Morardet, S., De Groot, R. and Grelot, F. 2008. The economic and livelihood value of provisioning services of the Ga-Mampa wetland, South Africa. 13th IWRA World Water Congress. 24.

Alekseevskiy, N.I., Berkovich, K.M., Chalov, R.S., 2008. Erosion, sediment transportation and accumulation in rivers. Int. J. Sediment Res. 23, 93–105. https://doi.org/10.1016/S1001-6279(08)60009-8.

Annon (Unknown) Determination of the trophic status of the Lephalala and Mokolo rivers and the prediction of future trophic changes through the use of microcosm studies. Unpublished report by the CISR.

Anthony, E.J., Goichot, M., Dussouillez, P., Dolique, F. and Nguyen, V.L. 2013. Task 19: Delta Stability Study. Report to WWF as part of AFD FFEM MRC Sediment Project.

Archibald, G.W., Sundar, KSG. and Barzen, J. (2003). A review of the three subspecies of Sarus Cranes Grus antigone. J. Ecol. Soc. 16: 5–15.

Baillie, J. and Groombridge, B. (eds). 1996. IUCN Red List of Threatened Animals. IUCN, Gland, Switzerland and Cambridge, UK.

Baker, N.J. 2018. An assessment of the aquatic macroinvertebrate diversity within the Nyl River Floodplain system, Limpopo, South Africa. MSc Thesis, University of Johannesburg.

Bejarano, M.D., Jansson, R., Nilsson, C., 2018. The effects of hydropeaking on riverine plants: a review. Biol. Rev. 93, 658–673. https://doi.org/10.1111/brv.12362.

Biggs, B.J.F. 1995. The contribution of disturbance, catchment geology and land-use to the habitat template of periphyton in stream ecosystems. Freshwater Biology 33: 419-438.

Biggs, B.J.F., Thomsen, H.A. 1995. Disturbance of stream periphyton by pertubations in shear stress: Time to structural failure and differences in community resistance. Journal of Phycology 31: 233-241.

Bilotta, G.S., Brazier, R.E. 2008. Understanding the influence of suspended solids on water quality and aquatic biota. Water Research 42: 2849-2861.

Birkhead, A.L. 2010. The role of Ecohydraulics in the South African Ecological Reserve. In: Ecohydraulics for South African Rivers, James, C.S. and King, J.M. (eds), Water Research Commission report no. TT K5/1767/1, Pretoria, South Africa.

Bornette, G. and Puijalon, S. 2011. Response of aquatic plants to abiotic factors: a review. Aquatic Science 73: 1-4.

Bouchard, R.W. 2004. Guide to aquatic macroinvertebrates of the upper midwest: Identification manual for students, citizen monitors and aquatic resource professionals. Water Resources Center, University of Minnesota, St. Paul. 215 pp.

Braccia, A. and Voshell, J.R. 2006. Benthic Macroinvertebrate Responses to Increasing Levels of Cattle Grazing in Blue Ridge Mountain Streams, Virginia, USA. Environ. Monit. Assess 131:185–200.

Brandt, S.A., 2000. Classification of geomorphological effects downstream of dams. CATENA 40, 375–401. https://doi.org/10.1016/S0341-8162(00)00093-X.

Bruyns, L. 2016. Investigating the relationship between coal usage and the change in cations and sulphate fluxes in three rivers in the Waterberg, South Africa. MSc Thesis, University of the Witwatersrand, Johannesburg.

Burcher, C.L., Smock L.A. 2002. Habitat distribution, dietary composition and life history characteristics of odonate nymphs in a blackwater coastal plain stream. American Midland Naturalist 148:75–89.

CABI. 2023. Commonwealth Agricultural Bureaux International, *Lagarosiphon illicifolius*, https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.30548, downloaded 27 April 2023.

Canadell, J., Jackson, R.B., Ehleringer, H.A., Sala, O.E., Schulze, E.D. 1996. Maximum rooting depth of vegetation types at the global scale. Oecologia 108: 583-595 Springer-Verlag.
CENTRE FOR FRESHWATER BIOLOGY. 2023. Centre for Freshwater Biology, University of New Hampshire, http://cfb.unh.edu, accessed on 14 September 2023.
Corbin, T.A. and Goonan, P. 2010. Habitat and Water Quality Preferences of Mayflies and Stoneflies from South Australian Streams. Transactions of the Royal Society of South Australia, Incorporated: incorporating the records of the South Australian Museum 134(1):5-18. DOI:10.1080/3721426.2010.10887129.
Covich A. P., and McDowell W. H. 1996. The stream community, pp. 433-459. In, Reagan D. P., Waide R. B. (eds.), The Food Web of a Tropical Rain Forest. University of Chicago Press, Chicago, IL.
Cummings, K.W. and R.W. Merritt. 1996. An Introduction to the Aquatic Insects of North America. Kendall and Hunt Publishing Company. Boston.
Dabrowski, J.M. 2015. Investigation of the Contamination of Water Resources by Agricultural Chemicals and the Impact on Environmental Health. Volume 2: Prioritizing human health effects and mapping sources of agricultural pesticides used in South Africa. WRC Report No. TT 642/15, Water Research Commission.
Dallas, H., Rivers-Moore, N (2022). A protocol and tools for setting environmental water temperature guidelines for perennial rivers in South Africa. African Journal of Aquatic Science, 1-16.
Dallas, H.F., Rivers-Moore, N.A. 2019. Environmental water temperature guidelines for perennial rivers in South Africa. Volume 2: A technical manual for setting water temperature targets. WRC Report No. TT 799/2/19. Water Research Commission.
Dallas, H.F., Day, J.A. 2004. The Effect of Water Quality Variables on Aquatic Ecosystems: A Review. WRC Report No. TT 224/04. Water Research Commission.
Dean, Charles, GM Selckmann. 2015. Ecology and Management of Filamentous Green Algae. ICPRB Report 15-7.
Dean, J and Suter, P. 1996. Mayfly Nymphs of Australia, A Guide to Genera. Co-operative Research Centre for Freshwater Ecology Identification Guide No.7. Identification Guide Series edited by J. H. Hawking First published 1996 by Co-operative Research Centre for Freshwater Ecology, Ellis Street, Thurgoona, Albury, NSW 2640.
De Grave, S, Cai, Y, and Anker, A. 2008. Global diversity of shrimps (Crustacea: Decapoda: Caridea) in freshwater. Hydrobiologia 595: 287- 293.
Department of Water Affairs and Forestry 2002. Aquatic Invertebrates of South African Rivers: Illustrations. Institute for Water Quality Studies. Department of Water Affairs and Forestry.
Department of Water Affairs (DWA). 2004. Water Resource Quality Monitoring. Volume 1: Sampling protocol for inorganic chemical analysis. Resource Quality Services, Department of Water Affairs, Pretoria.
Department of Water Affairs and Forestry (DWAF). 2004. Luvuvhu/Letaba Water Management Area: Internal Strategic Perspective. Prepared by Goba Moahloli Keeve Steyn (Pty) Ltd in association with Tlou and Matji, Golder Associates Africa and BKS on behalf of the Directorate: National Water Resource Planning. DWAF Report No. P WMA 02/000/00/0304.
Department of Water Affairs and Forestry (DWAF). 2008. Methods for determining the Water Quality component of the Ecological Reserve. Final draft. Prepared by P-A Scherman of Scherman Consulting.
Department of Water Affairs and Forestry (DWAF). 1996. South African Water Quality Guidelines. Volume 7: Aquatic Ecosystems.

Department of Water Affairs and Forestry (DWAF). 2008. Methods for determining the Water Quality component of the Ecological Reserve. Final draft. Prepared by P-A Scherman of Scherman Consulting.

Department of Water and Sanitation. 2014. A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. Secondary: A5-A9; B9. Compiled by RQIS-RDM: https://www.dwa.gov.za/iwqs/rhp/eco/peseismodel.aspx accessed on 2021/11/01.

Department of Water Affairs, South Africa. 2014. DEVELOPMENT OF A RECONCILIATION STRATEGY FOR THE LUVUVHU AND LETABA WATER SUPPLY SYSTEM: HYDROLOGY REPORT. Prepared by: WRP Consulting Engineers, DMM Development Consultants, Golder Associates Africa, Worley Parsons, Kyamandi, Hydrosol and Zitholele Consulting. Report No. P WMA 02/B810/00/1412/5

Department of Water Affairs, South Africa. 2015. LIMPOPO WATER MANAGEMENT AREA NORTH RECONCILLIATION STRATEGY: HYDROLOGY ANALYSIS. Prepared by: AECOM in association with Hydrosol, Jones & Wagner and VSA Rebotile Metsi Consulting. Report No. P WMA 01/000/00/02914/3

Department of Water and Sanitation (DWS). 2015. Development of a reconciliation strategy for the Luvuvhu and Letaba Water Supply System: Water requirements and return flows. Report submitted to Department of Water and Sanitation.

Department of Water and Sanitation (DWS). 2017. The development of the Limpopo Water Management Area North Reconciliation Strategy. Prepared by AECOM in association with Hydrosol, Jones & Wagner and VSA Rebotile Metsi Consulting. Report No. P WMA 01/000/00/02914/11B.

Department of Water and Sanitation. 2014. A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa. Secondary: A5-A9; B9. Compiled by RQIS-RDM: https://www.dwa.gov.za/iwqs/rhp/eco/peseismodel.aspx accessed on 2021/11/01.

Department of Water and Sanitation, South Africa. June 2022. Determination of Water Resource Classes, Reserve and Resource Quality Objectives Study for Secondary Catchments A5 – A9 within the Limpopo Water Management Area (WMA 1) and Secondary Catchment B9 in the Olifants Water Management Area (WMA 2): Delineation and Status Quo Report. Final. Report No.: WEM/WMA01&02/00/CON/RDM/0322

Dickens, C.W.S., Graham, P.M. 2002. The South African Scoring System (SASS) Version 5 Rapid Bio assessment Method for Rivers. African Journal of Aquatic Science 2002, 27: 1–10.

Dollar, E., Rowntree, K.M., 2003. Geomorphological Research for the Conservation and Management of South African Rivers. Volume 2: Managing Flow Variability: The Geomorphological response (Water Research Commission Report No. 849/2/03). Pretoria, South Africa.

Edokpayi, J.N., Odiyo, J.O., Popoola, E.O., Msagati, T.A.M. 2018. Evaluation of Microbiological and Physicochemical Parameters of Alternative Source of Drinking Water: A Case Study of Nzhelele River, South Africa. The Open Microbiology Journal, 12: 18-27.

Entwistle, N., Heritage, G., Tooth, S., Milan, D., 2015. Anastomosing reach control on hydraulics and sediment distribution on the Sabie River, South Africa, in: Proceedings of the International Association of Hydrological Sciences. Presented at the Sediment Dynamics from the Summit to the Sea - ICCE 2014, International Symposium On Sediment Dynamics, New Orleans, USA, 14 December 2014, Copernicus GmbH, pp. 215–219. https://doi.org/10.5194/piahs-367-215-2015.

Ewart-Smith, J.L. 2013. The relationship between periphyton, flow and nutrients in foothill rivers of the south-western Cape, South Africa. Unpublished PhD thesis, University of Cape Town, Cape Town, South Africa.
Fouche, P.S.O. 2009. Aspects of the ecology and biology of the Lowveld largescale yellowfish (Labeobarbus marequensis, Smith, 1843) in the Luvuvhu River, Limpopo River System, South Africa. PhD Thesis, University of Limpopo.
Fouche, P.S.O., Vlok, W. 2010. Water quality impacts on instream biota of the Shingwedzi River, South Africa. African Journal of Aquatic Science, 35(1): 1-11.
Fouché, P.S.O., Vlok, W., Roos, J.C., Luus-Powell, W., Jooste, A. 2013. Establishing the fishery potential of Lake Ṋanḍoni in the Luvuvhu River, Limpopo Province. WRC Report No. 1925/1/12, Water Research Commission, South Africa.
Friedman J.M., Lee, V.J. 2002. Extreme Floods, Channel Change, and Riparian Forests along Ephemeral Streams. Ecological Monographs, 72(3), pp. 409–425. Ecological Society of America.
Huxman, T.E., W Ilcox, B.P., Breshears, D.D., Scott, R.L., Snyder, K.A., Small, E.E., Hultine, K., P Ockman, W.T., Jackson, R.B. 2005. Ecohydrological Implications Of Woody Plant Encroachment. Ecology, 86(2) pp. 308–319 Ecological Society of America.
Fryirs, K.A., Brierley, G.J., 2013. Geomorphic Analysis of River Systems: An Approach to Reading the Landscape. John Wiley & Sons, Ltd, Chichester.
Godsmark, R., Oberholzer, F. 2019. The South African forestry and forest products industry 2018. Forestry South Africa.
Gordon, N., McMahon, T., Finlayson, B., Gippel, C., Nathan, R. 2004. Stream Hydrology: An Introduction for Ecologists, 2nd ed. John Wiley & Sons Ltd, Chichester.
Goudie, A., 2004. Encyclopedia of Geomorphology. Psychology Press.
Graf, W.L., 2006. Downstream hydrologic and geomorphic effects of large dams on American rivers. Geomorphology, 37th Binghamton Geomorphology SymposiumThe Human Role in Changing Fluvial Systems 79, 336–360. https://doi.org/10.1016/j.geomorph.2006.06.022
Griffin, N.J., Palmer, C.G., Scherman, P.A. 2014. Critical Analysis of Environmental Water Quality in South Africa: Historic and Current Trends. WRC Report No. 2184/1/14. Water Research Commission, Pretoria.
Griffiths, C, Day, J and Picker, M. 2015. Freshwater Life, A field guide to the plants and animals of southern Africa. Struik Nature. ISBN978-1-77584-102-9.
Heritage, G., Tooth, S., Entwistle, N., Milan, D. 2015. Long-term flood controls on semi-arid river form: evidence from the Sabie and Olifants rivers, eastern South Africa, in: Proceedings of the International Association of Hydrological Sciences. Presented at the Sediment Dynamics from the Summit to the Sea - ICCE 2014, International Symposium On Sediment Dynamics, New Orleans, USA, 14 December 2014, Copernicus GmbH, pp. 141–146. https://doi.org/10.5194/piahs-367-141-2015.
Hill, W.R. 1996. Effects of light. Pages 121-148 in R.H. Stevenson, M.L. Bothwell and R.L. Lowe (Eds.). Algal Ecology: Freshwater benthic ecosystems. Academic Press, San Diego.
Holomuzki, J.R., B.J.F. Biggs. 2006. Food limitation affects algivory and grazer perfomance for New Zealand stream macroinvertebrates. Hydrobiologia 561: 83-94.
Huchzermeyer, N.H., Rowntree, K., 2021. Developing a taxa-related physical habitat score based on the response of macroinvertebrate community structure to fine bed sediment composition in the Tsitsa River, Eastern Cape, South Africa. River Res. Appl. n/a, 1–14. https://doi.org/10.1002/rra.3857.
Huggins, D.G, DuBois, M.B. 1982. Factors affecting microdistribution of two species of burrowing dragonfly larvae with notes on their biology (Anisoptera: Gomphidae). Odonatologica (1), 1-14.

Huxman, T.E., W Ilcox, B.P., Breshears, D.D., Scott, R.L., Snyder, K.A., Small, E.E., Hultine, K., P Ockman, W.T., Jackson, R.B. 2005 Ecohydrological Implications of Woody Plant Encroachment. Ecology, 86(2) pp. 308–319 Ecological Society of America.

iNaturalist. 2023. https://www.inaturalist.org/taxa/173246-Caenidae, accessed 14 September 2023.

Jogo, W., Hassan, R. 2010. Balancing the use of wetlands for economic well-being and ecological security: The case of the Limpopo wetland in southern Africa. Ecol. Econ. 69: 1569–1579.

Jones JI, Murphy JF, Collins AL, Sear DA, Naden PS, Armitage PD. 2012. The Impact of Fine Sediment on Macro-Invertebrates. River Research and Applications 28(8):1055–1071. DOI: 10.1002/rra.1516.

Jooste, S, Bollmohr, S, Thwala, M. 2008. National Toxicity Monitoring Program: Report on Phase 3: Pilot Implementation and Testing of the Design. Report No. N/0000/REQ1008. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa

Kennedy, T.A., Muehlbauer, J.D., Yackulic, C.B., Lytle, D.A., Miller, S.W., Dibble, K.L., Kortenhoeven, E.W., Metcalfe, A.N., Baxter, C.V. 2016. Flow Management for Hydropower Extirpates Aquatic Insects; Undermining River Food Webs. BioScience 66(7):561–575. https://doi.org/10.1093/biosci/biw059.

King, JM, Tharme, RE, de Villiers MS. 2008. Environmental flow assessments for rivers: manual for the Building Block Methodology (Updated edition). Water Research Commission report number TT 354/08. Water Research Commission, Pretoria.

Kleynhans, C.J. and M.D. Louw. 2007a. Module A: EcoClassification and EcoStatus Determination in River EcoClassification: Manual for EcoStatus Determination (version 2).Water Research Commission Report No. TT 329/08. Joint Water Research Commission and Department of Water Affairs and Forestry report, Pretoria, South Africa.

Kleynhans, C.J., Mackenzie, J., Louw, M.D.. 2007. Module F: Riparian Vegetation Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report.

Kleynhans, C.J, Thirion, C, Moolman, J and Gaulana, L. 2007. A Level II River Ecoregion Classification System. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa.

Kleynhans, CJ., 2007. River Ecoclassification: Manual for ecostatus determination (version 2). Module D: Volume 1 Fish Response assessment Index (FRAI). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT330/08.

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

Kroeger, T., Klemz, C., Boucher, T., Fisher, J.R.B., Acosta, E., Cavassani, A.T., Dennedy-Frank, P.J., Garbossa, L., Blainski, E., Santos, R.C., Giberti, S., Petry, P., Shemie, D., Dacol, K. 2019. Returns on investment in watershed conservation: Application of a best practices analytical framework to the Rio Camboriú Water Producer program, Santa Catarina, Brazil. Sci. Total Environ. 657: 1368–1381.

Kuhnle, R., 1996. Unsteady transport of sand and gravel mixtures. Chichester, John Wiley. pp 183-202, in: Carling, P., Dawson, M. (Eds.), Advances in Fluvial Dynamics and Stratigraphy. John Wiley, Chichester, pp. 183–202.

Lee DY, Lee DS, Hwang SJ, Lee KL. 2022. Distribution patterns and vulnerability of stoneflies (Plecoptera: Insecta) in south Korean streams with conservation perspectives. Global Ecology and Conservation 34:e02030.

Leenhouts, J.M., Stromberg, J.C., Scott, R.L. 2005. Hydrologic Requirements of and Evapotranspiration by Riparian Vegetation along the San Pedro River, Arizona U.S. Geological Survey Scientific Investigations Report 2005–5163.
Letley, G., Turpie, J., Gardner, K., Kleynhans, M., Schmidt, K. Hassiem, R. 2022. Development of a Business Case for the Tamale Water Fund. Final Technical Report submitted by Anchor Environmental Consultants to Catholic Relief Services.
Lisle, T.E., Hilton, S. 1992. The Volume of Fine Sediment in Pools: An Index of Sediment Supply in Gravel-Bed Streams1. JAWRA J. Am. Water Resour. Assoc. 28, 371–383. https://doi.org/10.1111/j.1752-1688.1992.tb04003.x.
Lite S.J., Stromberg J.C. 2005. Surface water and ground-water thresholds for maintaining Populus - Salix forests, San Pedro River, Arizona. Biological Conservation 125: 153-167.
London, L, Dalvie, M A, Cairncross, E., Solomons, A. 2000. The quality of surface and groundwater in the rural Western Cape with regard to pesticides. Water Research Commission Report No. K5/795/01.
Long, A., Ashe, W., Ravana, K., Simon, K.S. 2011 The effects of water velocity and sediment size on *Acroneuria abnormis* (Plecoptera: Perlidae) entrainment. Aquatic Insects 33(2):105-112.
Louw MD and Birkhead AL 1998. Crocodile River Preliminary Reserve: Site Selection Process. Department of Water Affairs and Forestry, Pretoria.
MACROINVERTEBRATES. 2023. The Atlas of Common Freshwater Macroinvertebrates of Eastern North America, https://www.macroinvertebrates.org/ accessed 14 September 2023.
Madilonga, R.T.; Edokpayi, J.N.; Volenzo, E.T.; Durowoju, O.S.; Odiyo, J.O. 2021. Water Quality Assessment and Evaluation of Human Health Risk in Mutangwi River, Limpopo Province, South Africa. Int. J. Environ. Res. Public Health 2021, 18, 6765.
Malzacher, P, Staniczek, A.H. 2007. Caenis vanuatensis, a new species of mayflies (Ephemeroptera: Caenidae) from Vanuatu. Aquatic Insects December 2007; 29(4): 285 – 295.
Mathis, B.J., Myers, S.A. 1970. Community metabolism in Lower Peoria Lake. Transactions Illinois State Acacademy of Science 63: 207-213.
McNair, J., Newbold, J., Hart, D. 1997. Turbulent transport of suspended particles and dispersing benthic organisms: how long to hit bottom: Journal of Theoretical Biology 188:29-52.
Milan, D., Heritage, G., Entwistle, N., Tooth, S. 2018a. Morphodynamic simulation of sediment deposition patterns on a recently stripped bedrock anastomosed channel, in: Proceedings of the International Association of Hydrological Sciences. Presented at the Water quality and sediment transport issues in surface water - IAHS Scientific Assembly 2017, Port Elizabeth, South Africa, 10–14 July 2017, Copernicus GmbH, pp. 51–56. https://doi.org/10.5194/piahs-377-51-2018.
Milan, D., Heritage, G., Tooth, S., Entwistle, N. 2018b. Morphodynamics of bedrock-influenced dryland rivers during extreme floods: Insights from the Kruger National Park, South Africa. GSA Bull. 130, 1825–1841. https://doi.org/10.1130/B31839.1.
Milan, D.J., Tooth, S., Heritage, G.L. 2020. Topographic, Hydraulic, and Vegetative Controls on Bar and Island Development in Mixed Bedrock-Alluvial, Multichanneled, Dryland Rivers. Water Resour. Res. 56, e2019WR026101. https://doi.org/10.1029/2019WR026101.
Millennium Ecosystem Assessment. 2003. Ecosystems and Human Well-being: a Framework for Assessment. Island Press, Washington.
Mokgoebo, M.J. 2019. The use of Water Quality, Aquatic Species Composition and Aquatic Habitat Conditions to assess the River Health Condition of the Nzhelele River, Limpopo Province, South Africa. PhD thesis, University of South Africa.

Monyai, M., Makhado, R.A., Novhe, N.O. 2016. Water quality of the Luvuvhu River and its tributaries within the Thulamela Local Municipality, Limpopo Province, South Africa, African Journal of Science, Technology, Innovation and Development, 8 (5-6): 439-445.

Mucina, L. Rutherford, M.C. (eds). 2006-2018. The Vegetation of South Africa, Lesotho and Swaziland. Strelizia 19. South African National Biodiversity Institute, Pretoria.

Oberholster, P.J., Ashton, P.J., Fritz, G.B., Botha, A.M. 2010. First report on the colony-forming freshwater ciliate *Ophrydium versatile* in an African river. Water SA, 36(3): 315-322.

Odiyo, J.O., Makungo, R. 2012. Water quality problems and management in rural areas of Limpopo Province, South Africa. WIT Transactions on Ecology and The Environment, 164: 135-146.

Olivier, J., Venter, J.S., Jonker, C.Z. 2011. Thermal and chemical characteristics of hot water springs in the northern part of the Limpopo Province, South Africa. Water SA, 37(4): 427-436.

Palmer, C.G., Scherman. P.A., Muller, W.J., Rossouw, J.N., Malan, H.L., Jooste, S. 2004. Early Development of Water Quality Methods and Approaches in Ecological Reserve Assessments. WRC Report No.: 1108/1/04, Water Research Commission.

Peterson, J.L., Jepson, P.C., Jenkins, J.J. 2001. Effect of varying pesticide exposure duration and concentration on the toxicity of carbaryl to tow field-collected stream invertebrates, *Calineuria californica* (Plecoptoera: Perlidae) and *Cinygma* sp. (Ephemeroptera: Hemtageniidae). Environmental Toxicology and Chemistry 20(10):2215-2223.

Petts, G.E., Gurnell, A.M., 2005. Dams and geomorphology: Research progress and future directions. Geomorphology, Dams in Geomorphology 71, 27–47. https://doi.org/10.1016/j.geomorph.2004.02.015.

Phiri, C., Chakona, A., Day, J.A. 2012. Macroinvertebrates associated with two submerged macrophytes, *Lagarosiphon ilicifolius* and *Vallisineria aethiopica*, in the Sanyati Basin, Lake Kariba, Zimbabwe: effect of plant morphological complexity. African Journal of Aquatic Science 37(3): 277-288.

Phungula, P.P. 2018. The use of diatoms in assessing water quality in the Nyl and Mogalakwena River system, in the Limpopo, South Africa. Minor MSc dissertation, University of Johannesburg.

Pienaar, U. The Freshwater Fishes of the Kruger National Park, Koedoe Vol 11, No 1 (1968).

Ractliffe, G., Cullis, J., Rooseboom, A. 2008. Flood disturbance responses of invertebrate assemblages in two cobble-boulder bed rivers of the western Cape. WRC report no. 1411/2/08. ISBN 978-1-77005-646-6.

Rivers-Moore, N. A., de Moor, F. C. 2008. Impact of winter flow regulation on pest-level populations of blackfly (Diptera: Simuliidae) and non-target faunal communities in a South African river, African Journal of Aquatic Science, 33:2, 125-134.

Rominger, J.T., Lightbody, A.F., Nepf, H.M., 2010. Effects of Added Vegetation on Sand Bar Stability and Stream Hydrodynamics. J. Hydraul. Eng. 136, 994–1002. https://doi.org/10.1061/(ASCE)HY.1943-7900.0000215.

Rountree, M.W., Rogers, K.H., Heritage, G.L. 2000. Landscape State Change in the Semi-Arid Sabie River, Kruger National Park, in Response to Flood and Drought. South Afr. Geogr. J. 82, 173–181. https://doi.org/10.1080/03736245.2000.9713711.

Rowlston, B., Jordanova A.A. and Birkhead A.L., 2000. Hydraulics In: Environmental flow assessment for rivers: Manual for the Building Block Methodology, King, JM, Tharme, RE and de Villiers, MS, (eds), Water Research Commission (WRC) report no.TT 131/00, 340 pp. WRC, Pretoria, South AfricaRowntree, K.M., Wadeson, R.A. 1999. A hierarchical framework for categorising the geomorphology of river systems, Water Research Commission Report. 497/1/99. WRC, Pretoria.

Rowntree, K.M. and Wadeson, R.A. 1999. A hierarchical framework for categorising the geomorphology of river systems, Water Research Commission Report. 497/1/99. WRC, Pretoria.
Rowntree, K.M. 2013. Geomorphological Driver Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2) (Water Research Commission Report No. TT 551/13). Pretoria, South Africa.
Rowntree, K.M., Dollar, E.S.J. 1999. Vegetation controls on channel stability in the Bell River, Eastern Cape, South Africa. Earth Surf. Process. Landf. 24, 127–134. https://doi.org/10.1002/(SICI)1096-9837(199902)24:2<127::AID-ESP944>3.0.CO;2-3.
Rowntree, K.M., Du Plessis, A. 2003. Geomorphological research for the conservation and management of southern African rivers. Volume 1: geomorphological impacts of river regulation (No. WRC Report No 849/1/03). Pretoria, South Africa.
Rowntree, K.M., Wadeson, R.A., O'Keefe, J.O. 2000. The development of a geomorphological classification system for the longitudinal zonation of South African rivers. South African Geographical Journal 82(3): 163-172.
Samways, M.J., Osborn, R., Van Heerden, I. 1996. Distribution of benthic invertebrates at different depths in a shallow reservoir in the KwaZulu Natal Midlands. Koedoe 39: 69 – 76.
Schmutz, S., Moog, O. 2018. Dams: Ecological Impacts and Management, in: Riverine Ecosystem Management. Springer, pp. 111–127.
Schoonbee, H.J. 1973. The role of Ecology in the species evaluation of the genus *Afronurus* Lestage (Heptageniidae) in South Africa. IN Proceedings of the First International Conference on Ephemeroptera Edited by W.L. Peters and J.G. Peters.
Schulze, R.E., Maharaj, M. 2004. Development of a database of gridded daily temperatures for Southern Africa. WRC Report No. 1156/2/04, Water Research Commission.
Science Direct. 2023. https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/hydropsychidae#:~:text=Hydropsychidae%20(11%20Genera%2C%20158%20Species,sizes%2C%20currents%2C%20and%20temperatures, accessed on 25 October 2023.
Science Direct. 2023a. https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/heptageniidae, accessed on 25 October 2023.
Scott, K.M.F. 1988. Twenty-five years of Trichoptera research relating to Southern Africa-a personal view. Journal of the Limnological Society of Southern Africa 14.
Scott, L.E.P., Skelton, P.H., Booth, A.J., Verheust, L., Harris, R., Dooley, J. 2006. Atlas of southern African freshwater fishes. Smithiana, Monograph 2. The South African Institute for Aquatic Biodiversity.
Seanego, K.G. 2014. Ecological Status of the Sand River after the Discharge of Sewage Effluent from the Polokwane and Seshego Wastewater Treatment Works. MSc Thesis, University of Limpopo.
Seanego, K.G., Moyo, N.A.G. 2013. The effect of sewage effluent on the physico-chemical and biological characteristics of the Sand River, Limpopo, South Africa. Physics and Chemistry of the Earth, 66: 75-82.
Sekwele, R.C. 2008. Selected Heavy Metals Concentrations on Selected Samples of Naboom Spruit, Tobias Spruit and The Nyl Floodplain, South Africa. MSc Thesis, University of Limpopo.
Sennatt, K.M., Salant, N.L., Renshaw, C.E., Magilligan, F.J. 2006. Assessment of Methods for Measuring Embeddedness: Application to Sedimentation in Flow Regulated Streams1. JAWRA J. Am. Water Resour. Assoc. 42, 1671–1682. https://doi.org/10.1111/j.1752-1688.2006.tb06028.x.
Sivaruban, T., Barathy, S., Venkataraman, K., Arunachalam, M. 2010. Life cycle studies of Heptageniidae (Insecta Ephemeroptera) in Kumbbakarai Stream of Western Ghats, Tamil Nadu, India. Journal of Threatened Taxa, 2 (10) 1223-1226.

Skead, C. J. 2009. Historical plant incidence in southern Africa. Strelizia 24. South African National Biodiversity Institute, Pretoria.

Skelton, P.H., 2001. A complete guide to freshwater fishes of southern Africa. Struik Publishers (Pty) Ltd., Cape Town, South Africa. 395pp.

South African National Biodiversity Institute. National List of Threatened Ecosystems 2011 [vector geospatial dataset] 2011. Available from the Biodiversity GIS website.

South African National Biodiversity Institute 2006-2018. The Vegetation Map of South Africa, Lesotho and Swaziland, Mucina, L., Rutherford, M.C. and Powrie, L.W. (Editors), Online, http://bgis.sanbi.org/SpatialDataset/Detail/18, Version 2018.

Stats SA. 2012. South Africa Census 2011. Statistics South Africa.

Stats SA. 2020. Census of commercial agriculture, 2017: Financial and production statistics Limpopo. Statistics South Africa.

Step SA. 2018. CSIR MesoZone 2018v1 Dataset. CSIR, http://stepsa.org/socio_econ.html.

Thirion, C. 2007. Module E: Macroinvertebrate Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report.

Thirion, C. 2016. The Determination of Flow and Habitat Requirements for Selected Riverine Macroinvertebrates. Thesis submitted in fulfilment of the requirements for the degree Philosophiae Doctor in Zoology at the Potchefstroom Campus of the North-West University.

Thorp, J.H. and A.P. Covich. 2010. Ecology and Classification of North American Freshwater Invertebrates, pp. 587-657. Elsevier Inc. Boston.

TNC. 2015. Upper Tana-Nairobi Water Fund Business Case. Version 2. The Nature Conservancy: Nairobi, Kenya.

TROPICA. 2023. Tropical Aquatic Plants, Nymphaea lotus, https://tropica.com/en/plants/plantdetails/Nymphaealotus(019)/4432. Downloaded 27 April 2023.

Turpie, J.K., Clark, B.M. 2007. CAPE Estuaries Conservation Plan. Development of a Conservation Plan for temperate South African estuaries on the basis of biodiversity importance, ecosystem health and economic costs and benefits. CAPE Estuaries Programme.

Turpie, J.K., Joubert, A. 2001. Estimating potential impacts of a change in river quality on the tourism value of Kruger National Park: An application of travel cost, contingent and conjoint valuation methods. Water SA 27: 387–398.

UNDP-GEF Orange-Senqu Strategic Action Programme. 2013. EFR Monitoring Programme. Research Project on Environmental Flow Requirements of the Fish River and the Orange-Senqu River Mouth.

USEPA. 2003. The biological effects of Suspended and Bedded Sediment (SABS) in aquatic systems: A Review Internal Report; United States Environmental Protection Agency.

Vazques, R.F., Vimos-Lojano, D., Hampel, H. 2020. Habitat Suitability Curves for Freshwater Macroinvertebrates of Tropical Andean Rivers. Water 12:2703.

Venter, J.A., Fouché, P.S.O., Vlok, W. 2012. Current distribution of the southern barred minnow, Opsaridium peringueyi (Pisces: Cyprinidae), in South Africa: Is there reason for concern? African Zoology 45(2): 244–253.

Walmsley, R.D. 2000. Perspectives on Eutrophication of Surface Waters: Policy/Research Needs in South Africa. WRC Report No KV129/00. Water Research Commission.

Water Research Commission. 2003a. Guides to the Freshwater Invertebrates of Southern Africa. Volume 7: Insecta I. Ephemeroptera, Odonata & Plecoptera. Editors: IJ de Moor, JA Day & FC de Moor. WRC Report No. TT207/03.

Water Research Commission. 2003b. Guides to the Freshwater Invertebrates of Southern Africa. Volume 8: Insecta ll. Hemiptera, Megaloptera, Neuroptera, Trichoptera & Lepidoptera. Editors: IJ de Moor, JA Day & FC de Moor. WRC Report No. TT214/03.

Water Research Commission. 2003c. Guides to the Freshwater Invertebrates of Southern Africa. Volume 9: Diptera. Editors: IJ de Moor, JA Day & FC de Moor. WRC Report No. TT201/02.

WIKIPEDIA. 2023. Lagarosiphon major, https://en.wikipedia.org/wiki/Lagarosiphon_major, downloaded 27 April 2023.

Yam, R.S.W., Dudgeon, D. 2006. Production dynamics and growth of atyid shrimps (Decapoda: Caridina spp.) in 4 Hong Kong streams: the effects of sites, season, and species. Journal of North American Benthological Society 25(2):406-416.

Yatsuya, M, Ueno, M, Yamashita, Y. 2013. Life History of the Amphidromous Shrimp *Caridina Leucosticta* (Decapoda: Caridea: Atyidae) in the Isazu River, Japan. Journal of Crustacean Biology, Volume 33, Issue 4, P488 – 502.

APPENDIX A

The members of the rivers EWR assessment team are listed in **Table A1**

Table A1: EWR assessment team members

Position	Name	Organisation
EWR Assessment advisor	Prof Cate Brown	Southern Waters ER&C
EWR task team leader	Dr Karl Reinecke	Southern Waters ER&C
DRIFT DSS team leader	Dr Alison Joubert	Southern Waters ER&C
Hydrological modelling	Gerald Howard	Private
Hydraulic modelling	Dr Andrew Birkhead	Streamflow solutions
Water quality	Nico Rossouw	Private
Geomorphology	Dr Bennie van der Waal	Private
Riparian vegetation	James Mackenzie	MEDS cc
Aquatic invertebrates	Colleen Todd	Private
Fish	Dr Mathew Ross	Enviross
Socio-economics team leader	Dr Jane Turpie	Anchor Environmental
Socio-economics	Gwyn Letley	Anchor Environmental