REPORT NO: RDM/WMA11/00/CON/CLA/0314

CLASSIFICATION OF WATER RESOURCES AND DETERMINATION OF THE COMPREHENSIVE RESERVE IN THE MVOTI TO UMZIMKULU WATER MANAGEMENT AREA

PROJECT NUMBER: WP 10679

VOLUME 2: ECOCLASSIFICATION AND EWR ASSESSMENT ON THE MTAMVUNA, LOVU, UMNGENI, KARKLOOF AND UMNSUNDUZE RIVERS

JANUARY 2014

water affairs

Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

RfA11_2012

CLASSIFICATION OF WATER RESOURCES AND DETERMINATION OF THE COMPREHENSIVE RESERVE AND RESOURCE QUALITY OBJECTIVES IN THE MVOTI TO UMZIMKULU WATER MANAGEMENT AREA

VOLUME 2: ECOCLASSIFICATION AND EWR ASSESSMENT ON THE MTAMVUNA, LOVU, uMNGENI, KARKLOOF AND uMNSUNDUZE RIVERS

Report Number: RDM/WMA11/00/CON/CLA/0314

JANUARY 2014

REFERENCE

This report is to be referred to in bibliographies as:

Department of Water Affairs, South Africa, July 2013. Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Volume 2: EcoClassification and EWR assessment on the Mtamvuna, Lovu, uMngeni, Karkloof and uMnsunduze Rivers. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd.

DOCUMENT INDEX

Index Number	DWA Report Number	Report Title
1	*Report Number: RDM/WMA11/00/CON/CLA/0112*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Inception report**
2	*Report Number: RDM/WMA11/00/CON/CLA/0113*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Status quo assessment, IUA and biophysical node delineation and identification.**
3	*Report Number: RDM/WMA11/00/CON/CLA/0213*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **River Resource Units and EWR sites**
4	*Report Number: RDM/WMA11/00/CON/CLA/0313*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Desktop Estuary EcoClassification and EWR**
5	**Rivers EWR report Volumes**	
5.1	*Report Number: RDM/WMA11/00/CON/CLA/0114*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 1: EWR estimates of the River Desktop Biophysical Nodes**
5.2	**Report Number: RDM/WMA11/00/CON/CLA/0214**	**Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Volume 2: EcoClassification and EWR assessment on the Mtamvuna, Lovu, uMngeni, Karkloof and uMnsunduze Rivers**
5.3	*Report Number: RDM/WMA11/00/CON/CLA/0314*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 3: EcoClassification and EWR assessment on the Mkomazi, uMngeni and Mvoti Rivers**
5.4	*Report Number: RDM/WMA11/00/CON/CLA/0414*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 4: Specialist appendices**
6	*Report Number: RDM/WMA11/00/CON/CLA/0212*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **BHNR**
7	*Report Number: RDM/WMA11/00/CON/CLA/0514*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Water Resource Analysis Report**
8	**Operational Scenario and Management Class report volumes**	

8.1	*Report Number: RDM/WMA11/00/CON/CLA/0614*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area*: **Volume 1: River Ecological Consequences**
8.2	*Report Number: RDM/WMA11/00/CON/CLA/0714*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 2: Estuary Ecological Consequences**
8.3	*Report Number: RDM/WMA11/00/CON/CLA/0814*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 3: Estuary ecological consequences - specialist appendices (available electronically only)**
8.4	*Report Number: RDM/WMA11/00/CON/CLA/0914*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 4: Economic consequences**
8.5	*Report Number: RDM/WMA11/00/CON/CLA/1014*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 5: EGSA consequences**
8.6	*Report Number: RDM/WMA11/00/CON/CLA/1214*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 6: Water quality consequences**
8.7	*Report Number: RDM/WMA11/00/CON/CLA/1314*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 7: Recommended Management Classes.**
9	*Report Number: RDM/WMA11/00/CON/CLA/0115*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Stakeholder Report**
10	**Resource Quality Objectives report volumes**	
10.1	*Report Number: RDM/WMA11/00/CON/CLA/0215*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 1: Rivers and Wetlands EcoSpecs and TPCs**
10.2	*Report Number: RDM/WMA11/00/CON/CLA/0315*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Volume 2: Resource Water Quality Objectives and Groundwater RQOs**
11	*Report Number: RDM/WMA11/00/CON/CLA/0415*	*Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area:* **Main report**

DEPARTMENT OF WATER AFFAIRS

CHIEF DIRECTORATE: RESOURCE DIRECTED MEASURES

CLASSIFICATION OF WATER RESOURCES AND DETERMINATION OF THE COMPREHENSIVE RESERVE AND RESOURCE QUALITY OBJECTIVES IN THE MVOTI TO UMZIMKULU WATER MANAGEMENT AREA

VOLUME 2: ECOCLASSIFICATION AND EWR ASSESSMENT ON THE MTAMVUNA, LOVU, uMNGENI, KARKLOOF AND uMNSUNDUZE RIVERS

Approved for RFA by:

……………………………………. ……………………………………

Delana Louw *Date*

Project Manager

DEPARTMENT OF WATER AFFAIRS (DWA)

Approved for DWA by:

……………………………………. ……………………………………

Date

Chief Director: Water Ecosystems

AUTHORS

The information in this report was authored by the multi-disciplinary group of specialists involved. Contributions were provided as follows:

- *Delana Louw: EWR coordinator, EcoClassification and EWR scenario process, application of the Index of Habitat Integrity*
- *Dr Andrew Birkhead: Ecohydraulics*
- *Dr Andrew Deacon: Macroinvertebrates*
- *Prof Denis Hughes: Ecohydrology*
- *Shael Koekemoer: Diatoms*
- *Dr Pieter Kotze: Fish*
- *James Mackenzie: Riparian vegetation*
- *Dr Patsy Scherman: Water quality*

ACKNOWLEDGEMENTS

Comments received from DWA:
Ms Tovho Nyamande
Ms Mmaphefo Thwala

REPORT SCHEDULE

Version	Date
First draft	*January 2014*
Second draft	*March 2014*
Final	*May 2014*

EXECUTIVE SUMMARY

BACKGROUND

The Mvoti to Umzimkulu WMA encompasses a total catchment area of approximately 27,000 km^2 and occurs largely within Kwazulu-Natal. A small portion of the Mtamvuna River and the upper and lower segments of the Umzimkulu River straddle the Eastern Cape, close to the Mzimvubu and Keiskamma WMA in the south (DWA, 2011). The Chief Directorate: Resource Directed Measures of the Department of Water Affairs initiated a study during 2012 for the provision of professional services to undertake the Comprehensive Reserve, classify all significant water resources and determine the Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area. The integrated steps for the study are provided below.

Step	Description
1	*Delineate the units of analysis and Resource Units, and describe the status quo of the water resource(s) (completed).*
2	*Initiation of stakeholder process and catchment visioning (on-going).*
3	**Quantify the Ecological Water Requirements and changes in non-water quality ecosystem goods, services and attributes**
4	*Identification and evaluate scenarios within the integrated water resource management process.*
5	*Evaluate the scenarios with stakeholders.*
6	*Develop draft RQOs and numerical limits.*
7	*Gazette and implement the class configuration and RQOs.*

*This report forms **part** of Step 3, i.e. quantifying the Ecological Water Requirements (EWR). Using the results of the hotspot assessment (DWA, 2013a) and the Resource Unit delineation (DWA, 2013b); twelve EWR sites (key biophysical nodes) were selected for EWR determination of which five of these sites were assessed using a revised and extended Rapid Ecological Reserve Methodology (Level III). The method includes the determination of floods which are normally not part of a Rapid assessment.*

This report documents the results of the EcoClassification for these five sites and the EWR assessment at four of the five sites. The EWR could not be set at the uMnsunduze River as the issues are dominated by water quality problems.

STUDY AREA

The WMA extends from the town of Zinkwazi, in the north to Port Edward and on the south along the KwaZulu-Natal coastline and envelopes the inland towns of Underberg and Greytown up until the Drakensberg escarpment. The WMA spans across the primary catchment "U" and incorporates the secondary drainage areas of T40 (Mtamvuna River in Port Shepstone) and T52 (Umzimkulu River).

The five Rapid EWR sites are described in DWA (2013b) and listed below.

EWR site name	SQ[1]	River	Latitude	Longitude	Eco-Region (Level II)	Geomorphic Zone	Alt (m)	MRU[2]	Quat[3]
Mt_R_EWR1	*T40E-5601*	*Mtamvuna*	*-30.85608*	*30.07268*	*17.01*	*Lower Foothills*	*277*	*Mtamvuna B*	*T40E*
Lo_R_EWR1	*U70C-04859*	*Lovu*	*-30.09997*	*30.73603*	*17.01*	*Lower Foothills*	*44*	*Lovu D*	*U70D*
Mg_R_EWR1	*U20A-04253*	*uMngeni*	*-29.5125*	*30.09417*	*16.01*	*Lower Foothills*	*1081*	*uMngeni A*	*U20A*
Mg_R_EWR3	*U20E-04170*	*Karkloof*	*-29.4401*	*30.30328*	*16.03*	*Upper Foothills*	*738*	*Karkloof C*	*U20E*
Mg_R_EWR4	*U20J-04364*	*uMnsunduze*	*-29.60801*	*30.45041*	*16.03*	*Lower Foothills*	*602*	*Duzi C*	*U20J*

1 Sub Quaternary reach *2 Management Resource Unit* *3 Quaternary catchment*

ECOCLASSIFICATION RESULTS

MT_R_EWR1: MTAMVUNA RIVER

EIS: MODERATE
Highest scoring metrics were migration route for eel species in the system. Rare and endangered riparian species occur and therefore this reach is important in terms of refugia and critical riparian habitat.

PES: C

- *General loss of connectivity and bank modification due to overgrazing, trampling, alien invasive vegetation and wood removal in the riparian zones.*
- *Increased nutrients due to deteriorated water quality.*

REC: C
As the EIS was MODERATE no improvement was required. The REC was therefore set to maintain the PES. Due to non-flow related impacts on riparian vegetation, the EWR were set for the instream EC of a B.

Component	PES & REC
IHI Hydrology	A/B
Physico chemical	A/B
Fish	B/C
Invertebrates	B
Instream	B
Riparian vegetation	C/D
EcoStatus	C
Instream IHI	B/C
Riparian IHI	C
EIS	MODERATE

LO_R_EWR1: LOVU RIVER

EIS: MODERATE
Highest scoring metrics were diversity of habitat types and features, the reach is important for the migration of eel species and macroinvertebrates in the system and rare and endangered riparian species are present.

PES: B/C

- *Reduced base flows due to dams and general landuse in the upper catchment.*
- *Deteriorated water quality and increased sedimentation due to livestock farming, WWTW, sand mining and sugarcane farming.*
- *Alien invasive vegetation and wood removal in the riparian zones.*

REC: B/C
EIS was MODERATE and the REC was therefore to maintain the PES.

Component	PES & REC
IHI Hydrology	B
Physico chemical	B/C
Fish	B/C
Invertebrates	B/C
Instream	B/C
Riparian vegetation	B/C
EcoStatus	B/C
Instream IHI	B/C
Riparian IHI	B/C
EIS	MODERATE

MG_R_EWR1: MGENI RIVER

EIS: LOW
Highest scoring metrics were diversity of habitat types and features as well as the presence of rare and endangered riparian species.

PES: C/D
- *The presence of aggressive alien fish species and exotic vegetation species.*
- *Some decrease in base flows due to abstractions for agriculture.*

REC: C/D
As the EIS was LOW no improvement was required. The C/D EcoStatus PES mainly due to non-flow related impacts and not representative of flow related problems in the reach. It was decided to exclude alien fish species from the assessment resulting in a PES of a C EC for fish and an instream PES of a C EC for which flow requirements were set.

Component	PES & REC
IHI Hydrology	B
Physico chemical	B
Fish	D (C)
Invertebrates	C
Instream	C/D (C)
Riparian vegetation	C/D
EcoStatus	C/D
Instream IHI	C
Riparian IHI	C
EIS	LOW

MG_R_EWR3: KARKLOOF RIVER

EIS: HIGH
The reach falls within a private nature reserve and serves as critical instream refuge from uMngeni which is impacted by bottom releases from Midmar Dam at times. Rare and endangered riparian species occur and therefore this reach is important in terms of refugia and critical riparian habitat.

PES: B
- *Reduced baseflows due to upstream irrigation activities.*
- *Localised impacts of roads, small farm dams, crossings and water quality problems from upstream irrigation.*

REC: B
Although the EIS was HIGH, the instream components were all in a B EC and therefore no improvement was required. The REC was therefore set to maintain the PES.

Component	PES & REC
IHI Hydrology	B
Physico chemical	B
Fish	B/C
Invertebrates	B
Instream	B
Riparian vegetation	B
EcoStatus	B
Instream IHI	C
Riparian IHI	B
EIS	HIGH

MG_R_EWR4: MSUNDUZE RIVER

EIS: LOW

Highest scoring metrics were diversity of habitat types and features as well as the presence of rare and endangered riparian species

PES: D/E

- *Increased floods and baseflows that exceed thresholds are important flow related impacts in the reach.*
- *Water quality is the major impact which drives the deteriorated ecological condition and is exacerbated by poor sewer infrastructure and industrial pollution leading to low oxygenation rates, high faecal coliform counts and excessive nutrient loading within the system.*
- *Intense alien vegetation infestation also impacts the reach severely.*

REC: D

As the EIS was LOW no improvement was required. All components were in an unsustainable EC (lower than a D EC), and therefore the REC had to be set at a D. As the water quality issues are the primary problem, these need to be addressed at source first prior to any attention being given to addressing the flow issues. Therefore, no flow requirement was set for this EWR site.

Component	PES	REC
IHI Hydrology	E/F	N/A
Physico chemical	E/F	D
Fish	E	D
Invertebrates	E	D
Instream	E	D
Riparian vegetation	D/E	D
EcoStatus	D/E	D
Instream IHI	E/F	D
Riparian IHI	D/E	D
EIS	LOW	LOW

EWR QUANTIFICATION

The final flow requirements are expressed as a percentage of the Natural Mean Annual Runoff

				Long term mean					
EWR site	**PES and REC**	**nMAR (MCM)**	**pMAR (MCM)**	**Low flows (MCM)**	**Low flows (%nMAR)**	**High flows (MCM)**	**High flows (%nMAR)**	**Total flows (MCM)**	**TOTAL (%nMAR)**
Mt_R_EWR1	*Instream: B*	*233.15*	*200.69*	*60.99*	*26.20*	*35.08*	*15.00*	*96.07*	*41.20*
Lo_R_EWR1	*B/C*	*87.76*	*73.42*	*20.04*	*22.80*	*13.19*	*15.10*	*33.23*	*37.90*
Mg_R_EWR1	*Instream: C*	*79.22*	*60.46*	*10.88*	*13.70*	*9.86*	*12.50*	*20.74*	*26.20*
Mg_R_EWR3	*B*	*70.11*	*56.50*	*19.11*	*27.30*	*11.38*	*16.20*	*30.49*	*43.50*

CONCLUSIONS AND RECOMMENDATIONS

The confidence in the EcoClassification is generally moderate which is acceptable for a Rapid assessment. Furthermore, no further work on the EcoClassification is required as it will not influence the EWR determination. However, monitoring is essential to ensure that the ecological objectives in terms of the REC are achieved.

The hydraulics and resulting low confidence at the Mg_R_EWR1 site would require additional hydraulic work (resurvey, photographs, EWR assessment) if any future developments or changes in operation are planned that could require a higher confidence EWR.

The low to moderate confidence of the Mg_R_EWR3 (Karkloof River) can be improved by additional hydraulic calibrations and revision of the EWR. Again this would only be required if any future developments or changes in operation are planned that could require a higher confidence EWR.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

TERMINOLOGY AND ACRONYMS

AEC	*Alternative Ecological Category*
ASPT	*Average Score Per Taxon*
BBM	*Building Block Methodology*
CD: RDM	*Chief Directorate: Resource Directed Measures*
D:RQS	*Directorate: Resource Quality Services*
DO	*Dissolved Oxygen*
DRIFT	*Downstream Response to Imposed Flow Transformation*
DWA	*Department Water Affairs (Name change applicable after April 2009*
DWAF	*Department Water Affairs and Forestry*
EC	*Ecological Category*
EI-ES	*Ecological Importance and Ecological Sensitivity*
EIS	*Ecological Importance and Sensitivity*
EWR	*Ecological Water Requirements*
FRAI	*Fish Response Assessment Index*
FROC	*Frequency of Occurrence*
HFSR	*Habitat Flow Stressor Response method*
IHI	*Index of Habitat Integrity*
LB	*Left bank*
MAR	*Mean Annual Runoff*
MC	*Management Class*
MCB	*Macro Channel Bank*
MCM	*Million Cubic Meters*
MIRAI	*Macroinvertebrate Response Assessment Index*
MRU	*Management Resource Unit*
nMAR	*Natural Mean Annual Runoff*
PAI	*Physico-chemical Driver Assessment Index*
PES	*Present Ecological State*
pMAR	*Present Day Mean Annual Runoff*
Quat	*Quaternary catchment*
RB	*Right bank*
RC	*Reference Condition*
RDRM	*Revised Desktop Reserve Model*
REC	*Recommended Ecological Category*
RERM	*Rapid Ecological Reserve Methodology*
RQO	*Resource Quality Objective*
SANBI	*South African National Biodiversity Institute*
SASS5	*South African Scoring System version 5*
SQ	*Sub Quaternary*
SRP	*Soluble Reactive Phosphate*
SRP	*Soluble Reactive Phosphate*
TIN	*Total Inorganic Nitrogen*
TWQR	*Target Water Quality Range*
UW	*Umgeni Water*
VEGRAI	*Riparian Vegetation Response Assessment Index*
WMA	*Water Management Area*
WWTW	*Waste Water Treatment Work*
Velocity Depth Classes: Fish and Macro-invertebrates	
FD	*Fast deep fish habitat*

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

1 INTRODUCTION

1.1 BACKGROUND

There is an urgency to ensure that water resources in the Mvoti to Umzimkulu Water Management Area (WMA) are able to sustain their level of uses and be maintained at their desired states. The determination of the Management Classes (MC) of the significant water resources in Mvoti to Umzimkulu WMA will ensure that the desired condition of the water resources, and conversely, the degree to which they can be utilised is maintained and adequately managed within the economic, social and ecological goals of the water users (DWA, 2011). The Chief Directorate: Resource Directed Measures (CD: RDM) of the Department of Water Affairs (DWA) initiated a study during 2012 for the provision of professional services to undertake the Comprehensive Reserve, classify all significant water resources and determine the Resource Quality Objectives (RQOs) in the Mvoti to Umzimkulu WMA.

1.2 STUDY AREA

The Mvoti to Umzimkulu WMA encompasses a total catchment area of approximately 27,000 km^2 *and occurs largely within Kwazulu-Natal. A small portion of the Mtamvuna River and the upper and lower segments of the Umzimkulu River straddle the Eastern Cape, close to the Mzimvubu and Keiskamma WMA in the south (DWA, 2011).*

The WMA extends from the town of Zinkwazi, in the north to Port Edward and on the south along the KwaZulu-Natal coastline and envelopes the inland towns of Underberg and Greytown up until the Drakensberg escarpment. The WMA spans across the primary catchment "U" and incorporates the secondary drainage areas of T40 (Mtamvuna River in Port Shepstone) and T52 (Umzimkulu River). Ninety quaternary catchments constitute the water management area and the major rivers draining this WMA include the Mvoti, uMngeni, Mkomazi, Umzimkulu and Mtamvuna (DWA, 2011).

Two large river systems, the Umzimkulu and Mkomazi rise in the Drakensberg. Two medium-sized river systems the uMngeni and Mvoti rise in the Natal Midlands and have been largely modified by human activities, mainly intensive agriculture, forestry and urban settlements. Several smaller river systems (e.g. Mzumbe, Mdloti, Tongaat, Fafa, and Lovu Rivers) also exist within the WMA (DWAF, 2004). Sseveral parallel rivers arise in the escarpment and discharges into the Indian Ocean and the water courses in the study area display a prominent southeasterly flow direction (DWA, 2011).

The WMA is very rugged and very steep slopes characterise the river valleys in the inland areas for all rivers and moderate slopes are found but comprise only 3% of the area of the WMA (DWAF, 2004).

1.3 INTEGRATED STEPS APPLIED IN THIS STUDY

The integrated steps for the National Water Classification System, the Reserve and RQOs are supplied in Table 1.1.

Table 1.1 Integrated study steps

Step	Description
1	*Delineate the units of analysis and Resource Units, and describe the status quo of the water resource(s) (completed).*
2	*Initiation of stakeholder process and catchment visioning (on-going).*
3	**Quantify the Ecological Water Requirements and changes in non-water quality ecosystem goods, services and attributes**
4	*Identification and evaluate scenarios within the integrated water resource management process.*
5	*Evaluate the scenarios with stakeholders.*
6	*Develop draft RQOs and numerical limits.*
7	*Gazette and implement the class configuration and RQOs.*

*This task forms **part** of Step 3, i.e. quantifying the Ecological Water Requirements (EWR). Using the results of the hotspot assessment (DWA, 2013a) and the Resource Unit (RU) delineation (DWA, 2013b); twelve EWR sites (key biophysical nodes) were selected for EWR determination. Five of these sites were assessed using the Rapid Ecological Reserve Methodology (Level III). The method was expanded to include the determination of floods which are normally not part of a Rapid assessment.*

This report documents the results of the EcoClassification for these five sites and the EWR assessment at four of these five sites. The EWR could not be set at the uMnsunduze River as the issues are dominated by water quality problems.

1.4 EWR SITES

The five EWR sites are described in DWA (2013b) and listed in Table 1.2.

Table 1.2 Five EWR sites (Rapid III level)

EWR site name	SQ[1]	River	Latitude	Longitude	Eco Region (Level II)	Geomorphic Zone	Alt (m)	MRU[2]	Quat[3]
Mt_R_EWR1	*T40E-5601*	*Mtamvuna*	*-30.85608*	*30.07268*	*17.01*	*Lower Foothills*	*277*	*Mtamvuna B*	*T40E*
Lo_R_EWR1	*U70C-04859*	*Lovu*	*-30.09997*	*30.73603*	*17.01*	*Lower Foothills*	*44*	*Lovu D*	*U70D*
Mg_R_EWR1	*U20A-04253*	*uMngeni*	*-29.5125*	*30.09417*	*16.01*	*Lower Foothills*	*1081*	*uMngeni A*	*U20A*
Mg_R_EWR3	*U20E-04170*	*Karkloof*	*-29.4401*	*30.30328*	*16.03*	*Upper Foothills*	*738*	*Karkloof C*	*U20E*
Mg_R_EWR4	*U20J-04364*	*uMnsunduze*	*-29.60801*	*30.45041*	*16.03*	*Lower Foothills*	*602*	*Duzi C*	*U20J*

1 Sub Quaternary reach *2 Management Resource Unit* *3 Quaternary catchment*

1.5 DATA AND INFORMATION AVAILABILITY

Information collated during physical surveys was used to provide the results in this report. The data and information availability is summarised in Table 1.3.

Table 1.3 Data and information availability

Data and Information Availability
Hydrology ▪ *Mtamvuna River: Mt_R_EWR1* o *Natural hydrology: Was derived from information obtained from the WR2012 study currently being undertaken. Although records have been extended, no recalibration of the WRSM2000 Model has yet been done (i.e. interim results were used for this assessment). Confidence: 2* o *Present Hydrology: The high resolution WRSM2000 system configuration obtained from the WR2012 Study was refined to include simulation of flows at the EWR site. Catchment developments (forestry, alien vegetation and irrigation water use) were disaggregated based on catchment area scaling. Confidence 1* o *Record period: No reliable gauge: WR2012 - 1920 – 2009.* ▪ *Lovu River: Lo_R_EWR1* o *Natural hydrology: The hydrology was derived from information obtained from the WR2012 study currently being undertaken. Although records have been extended no recalibration of the WRSM2000 Model has yet been done (i.e. interim results were used for this assessment). Confidence: 2* o *Present Day hydrology: The high resolution WRSM2000 system configuration obtained from the WR2012 Study was refined to include simulation of flows at the EWR site. Catchment developments (forestry, alien vegetation and irrigation water use) were disaggregated based on catchment area scaling. Confidence: 1* o *Record period: No reliable gauge: WR2012 - 1920 – 2009.* ▪ *uMngeni River: Mg_R_EWR1* o *Natural hydrology: Was derived from a detailed hydrological assessment. Confidence: 4.* o *Present Hydrology: The high resolution WRPM system configuration was refined to include simulation of flows at the EWR site. Catchment developments (forestry, small dams and irrigation water use) were disaggregated based on information obtained from WR2005 and catchment area scaling. Confidence 3.* o *Record period: U2H013 downstream of site (1960 – 2013).* ▪ *Karkloof River: Mg_R_EWR3* o *Natural hydrology: Was derived from a detailed hydrological assessment. Confidence: 4.* o *Present Hydrology: The high resolution WRPM system configuration was refined to include simulation of flows at the EWR site. Catchment developments (forestry, small dams and irrigation water use) were disaggregated based on information obtained from WR2005 and catchment area scaling. Confidence 3.* o *Record period: U2H006 upstream of site (1954 – 2013).*
Physico-chemical variables ▪ *Mtamvuna River: Mt_R_EWR1* o *Reference Condition was represented by the A category benchmark tables in DWAF (2008). This was considered suitably representative of the natural state in the area.* o *T4H001Q01 (WMS code 102600) (n = 403; 1978 - 2013) was used for the present state assessment and is the only water quality monitoring point in the area is on the Mtamvuna River and in the same Level II EcoRegion (i.e. 17.01) but well upstream of the EWR site.* *Confidence: 3* ▪ *Lovu River: Lo_R_EWR1* o *Reference Condition was represented by the A category benchmark tables in DWAF (2008). This was considered suitably representative of the natural state in the area.* o *There are only two active water quality gauging weirs in the U7 catchment area which contains the Lovu River. U7H007Q01 (WMS code 102687) on the Lovu River at Beaulieu Estate in U70B upstream of Richmond and well upstream of the EWR site in Level II EcoRegion 16.03. Samples have been collected from 1977 to 2013 (n=445) and U7H008Q01 (WMS code 102688) on the downstream weir of the Nungwane Dam on the Nungwane River in U70D. Samples have been collected from 1990 – 2013; n = 1 453; Level II EcoRegion 17.01.* o *There are also two Umgeni Water (UW) sites on the Nungwane River; one at the inflow to the dam and one at the outflow to the dam. Data from the INFLOW site was also used for the Lovu River assessment (i.e. UW site RNW001) (n = 59; metals: n = ± 4).* *Confidence: 3* ▪ *uMngeni River: Mg_R_EWR1* o *Reference Condition was represented by the A category benchmark tables in DWAF (2008). This was considered suitably representative of the natural state in the area.* o *The gauging weir, U2H013Q001 and both the EWR site and Umgeni Water sampling site, RMG001, are all at*

Data and Information Availability
the same geographical position. Note that the data record for the gauging weir is from 1977 - 1995, while UW data are available from 2008 – 2013 (n = 60). The latter data were therefore used to represent present state. *Confidence: 3* ▪ *Karkloof River: Mg_R_EWR3* o *Reference Condition was represented by the A category benchmark tables in DWAF (2008). This was considered suitably representative of the natural state in the area.* o *There is no UW site on the Karkloof River, with the only DWA gauging weir being well upstream in a different Level II EcoRegion. The data record for this gauging weir, i.e. U2H006Q01 (WMS code 102624), is from 1970 - 2013, with 903 data records. Data used for the present state assessment was therefore from 2008 – 2013 (n = 60+; F: n = 50).* *Confidence: 1* ▪ *uMnsunduze River: Mg_R_EWR4* o *Reference Condition was represented by the A category benchmark tables in DWAF (2008). This was considered suitably representative of the natural state in the area.* o *The gauging weir, U2H041Q001 (Msunduze River @ Hamstead Park) and both the EWR site and UW sampling site, RMD019 (Duzi at Motocross), are all at the same geographical position downstream of Pietermaritzburg and Darville WWTW. Note that the data record for the gauging weir is from 1985 - 2013 (n = 2 046), while UW data are available from 2008 - 2013. Both data sources were used to represent present state:* o *DWA site U2H041, WMS code 102651: n = 115+; 2008 - 2013; F: n = 54* o *UW site RMD019, n = 50+; metals: n = ± 20* *Confidence: 3*
Riparian vegetation ▪ *Data collected during site visit (August 2013).* ▪ *Historical anecdotal information on the vegetation of the area from 1790 to 1822 (Skead, 2009).* ▪ *Vegetation Biomes, Bioregions and Vegetation Types (Mucina & Rutherford, 2006).* ▪ *South African National Biodiversity Institute (SANBI) distribution data of plant species (SANBI POSA, 2009).* ▪ *Google Earth © satellite imagery.* ▪ *Historical aerial photographs.* ▪ *Hydraulic rating curves and lookup tables for each site.* ▪ *2013 desktop Present Ecological State (PES), Ecological Importance and Ecological Sensitivity (EI-ES) (DWA, 2013c).* *Confidence: 3*
Fish ▪ *Single site visit (August 2013).* ▪ *Limited historic data for river system.* ▪ *2013 desktop PES, EI-ES (DWA, 2013c).* ▪ *Atlas of Southern African Freshwater fishes (Scott et al., 2006).* ▪ *Reference Fish Frequency of Occurrence (FROC) Report (Kleynhans and Louw, 2007a).* *Confidence: 2*
Macroinvertebrates ▪ *Single site visit (August 2013).* ▪ *Extensive historic data for the river system available - River Health Programme database (1993 - 2013).* ▪ *2013 desktop PES, EI-ES (DWA, 2013b).* *Confidence: 3*
Diatoms *Diatom samples were taken during June and August 2013 at EWR sites in the Lovu, Karkloof and Mtamvuna. The uMngeni and uMnsunduze EWR sites were only sampled once during this period. Limited existing data was available at all sites and the only additional information that could be sourced was for the uMnsunduze and Lovu river (GroundTruth Consulting, 2006; 2010).* *Confidence: 2*

1.6 OUTLINE OF REPORT

The report structure is outlined below.

Chapter 1: Introduction

This chapter provides an overview of the study area, objectives of the study and data availability.

Chapter 2: Approach

This chapter outlines the methods followed during the Ecological Reserve process. Summarised methods are provided for the EcoClassification and EWR scenario determination.

Chapter 3, 5, 7, 9, and 11: EcoClassification
The EcoClassification results are provided for each EWR site.

Chapter 4, 6, 8 and 10: EWR Requirements
These chapters provide results of different EWR scenarios with respect to low and high flows for the respective EWR sites. Aspects covered in these chapters are component and integrated/stress curves, generating stress requirements, determining high flows and final results.

Chapter 12: Conclusions
The EcoClassification and EWR scenario results are summarised and recommendations are made

Chapter 13: References
Report references are listed.

Chapter 14: Appendix A: Water Quality Present State Assessment: Rapid EWR Sites
This appendix details the approach and results of the water quality assessment undertaken at all the EWR sites.

Chapter 15: Appendix B: Diatoms Results
This appendix details the approach and results of the diatom assessment undertaken at all the EWR sites.

Chapter 16: Appendix C: RDRM Output files
The output files are provided for all EWR sites except Mg_R_EWR4.

Chapter 17: Appendix D: Report Comments

2 APPROACH

The Rapid Ecological Reserve Methodology (RERM) (Level III) (DWAF, 1999) was followed and extended to achieve higher confidence by adding a flood component. Associated with the RERM is the EcoClassification process at Level III. The approaches are summarised below.

2.1 ECOCLASSIFICATION

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

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

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

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

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

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

2.1.1 Present Ecological State

The steps followed in the EcoClassification process are as follows:

- *Determine reference conditions for each component.*
- *Determine the PES for each component, as well as for the EcoStatus which represents an integrated PES for all components.*
- *Determine the trend for each component, as well as for the EcoStatus.*
- *Determine the reasons for the PES and whether these are flow or non-flow related.*
- *Determine the Ecological Importance and Sensitivity (EIS) for the biota and habitat.*

▪ *Considering the PES and the EIS, suggest a realistic Recommended Ecological Category (REC) for each component, as well as for the EcoStatus.*

The Level 3 EcoStatus assessment was applied according to standard methods. The minimum tools required for this assessment are shown in Figure 2.1 (modified from Kleynhans and Louw, 2007b).

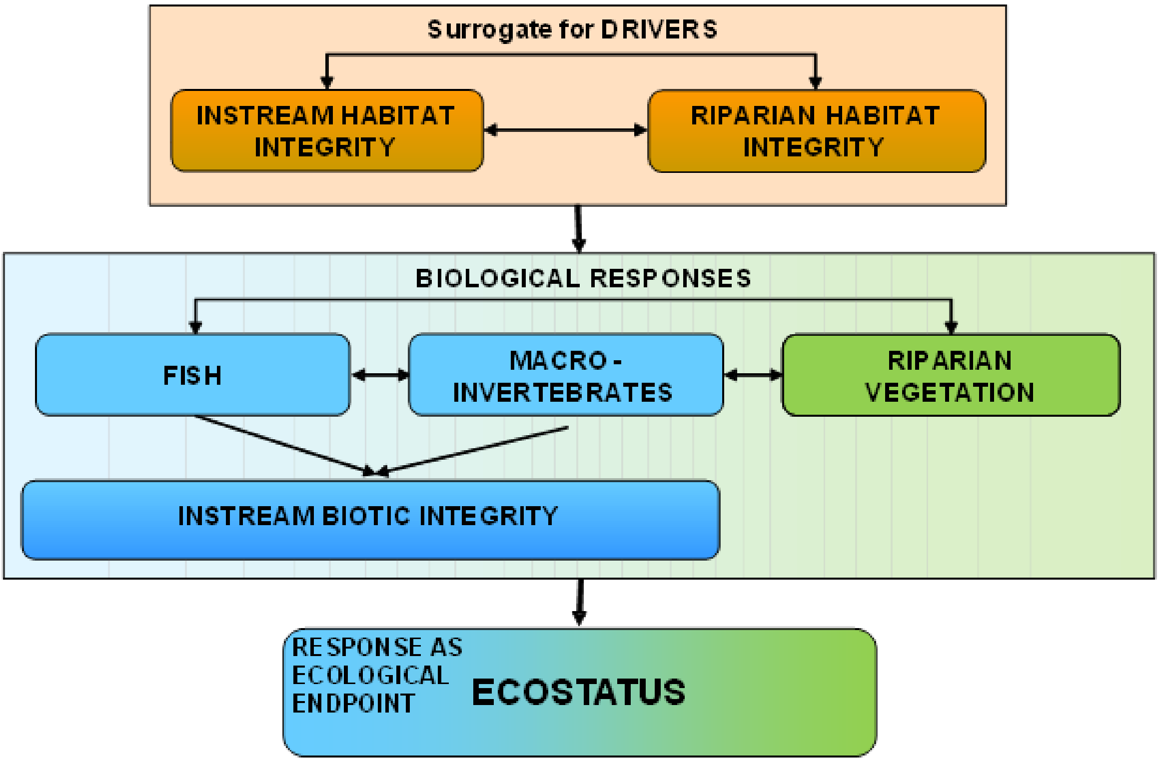

Figure 2.1 EcoStatus Level 3 determination

The role of the EcoClassification process is, amongst others, to define the various Ecological Categories (ECs) for which EWRs will be set. It is therefore an essential step in the EWR process. The EWR process is essentially a scenario-based approach and the EWRs determined for a range of ECs are referred to as EWR scenarios. The range of ECs could include the PES, REC (if different from the PES) and the Alternative Ecological Categories (AECs). When designing a scenario that could decrease the PES, flow changes are first to be evaluated. If this, and the response of other drivers, are deemed to be insufficient on its own to change the category, then the current non-flow related impacts are 'increased', or new non-flow related impacts are included. It is attempted to create a realistic scenario, however, it must be acknowledged that there are many scenarios that could result in a changed EC.

2.1.2 Ecological Importance and Sensitivity

The EIS was calculated using a refined (from Kleynhans and Louw, 2007b and Louw et al., 2010) EIS model which was developed during 2010 by Dr Kleynhans. This approach estimates and classifies the EIS of the streams in a catchment by considering a number of components surmised to be indicative of these characteristics.

The following ecological aspects are considered as the basis for the estimation of EIS:

- *The presence of rare and endangered species, unique species (i.e., endemic or isolated populations) and communities, intolerant species and species diversity were taken into account for both the instream and riparian components of the river.*
- *Habitat diversity was also considered. This included specific habitat types such as reaches with a high diversity of habitat types, i.e., pools, riffles, runs, rapids, waterfalls, riparian forests, etc.*

With reference to the bullets above, biodiversity in its general form (i.e. Noss, 1990) is taken into account as far as the available information allowed:

- *The importance of a particular river or stretch of river in providing connectivity between different sections of the river, i.e., whether it provided a migration route or corridor for species, was considered.*
- *The presence of conservation or relatively natural areas along the river section also served as an indication of ecological importance and sensitivity.*
- *The sensitivity (or fragility) of the system and its resilience (i.e., the ability to recover following disturbance) of the system to environmental changes was also considered. Consideration of both the biotic and abiotic components was included here.*

The EIS results of the study are summarised in this report and the models are provided electronically. EIS categories are summarised in Table 2.1.

Table 2.1 EIS categories (Modified from DWAF, 1999)

EIS Categories	General Description
Very high	*Quaternaries/delineations that are considered to be unique on a national or even international level based on unique biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are usually very sensitive to flow modifications and have no or only a small capacity for use.*
High	*Quaternaries/delineations that are considered to be unique on a national scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) may be sensitive to flow modifications but in some cases, may have a substantial capacity for use.*
Moderate	*Quaternaries/delineations that are considered to be unique on a provincial or local scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are usually not very sensitive to flow modifications and often have a substantial capacity for use.*
Low/Marginal	*Quaternaries/delineations that are not unique at any scale. These rivers (in terms of biota and habitat) are generally not very sensitive to flow modifications and usually have a substantial capacity for use.*

2.2 EWR DETERMINATION

The Habitat Flow Stressor Response method (HFSR) (O'Keeffe et al., 2002; IWR S2S, 2004; Hughes and Louw, 2010), a modification of the Building Block Methodology (BBM) (King and Louw, 1998) was used to determine the EWRs. This method is one of the methods used to determine EWRs at a detailed level and a basic version of this has been built into the Revised Desktop Reserve Model (RDRM) (Hughes et al., 2011).

The RERM requires the RDRM to be run and the results verified and adjusted by the specialists. The hydraulic information and survey data is used to aid in the verification.

The process to determine EWRs are summarised below.

2.2.1 Low flows

Step A: Determining the stress index

The basic approach is to compile stress indices for fish and macroinvertebrates. The stress index describes the consequences of flow reduction on flow dependent biota (or guilds) and is determined by assessing the response of critical habitat, and hence the indicator guild, to a flow reduction. The stress index therefore describes the habitat conditions and biota response for fish and macroinvertebrates at a range of low flows.

The stress index is described as an instantaneous response of habitat to flow in terms of a 0 to 10 index relevant for the specific site where:

- *0 - Optimum habitat with least amount of stress possible for the indicator groups (fixed at the natural maximum base flow which was based on the 20% annual value using separated natural baseflows for this study).*
- *10 - Zero discharge (Note: Surface water may still be present). Maximum stress on indicator group.*
- *2 to 9: Gradual decrease in habitat suitability and increase in stress as a result of decreased discharge.*

A process using the hydraulic and hydrology information has been built into the RDRM (Hughes et al., 2011).

Step B: Determining the low flow EWR

The stress index is then used to convert separate natural and present day flow time series to a stress time series. The stress time series is converted to a stress duration graph. This then provides the specialist with the information of how much the stress has changed from natural under present conditions due to changes in flow. It would follow that if flow has decreased from natural, stress would increase and vice versa. If specialists do not agree with the levels of stress under natural conditions based on their knowledge of the species, the stress indices can be refined to a limited extent.

The ecological sub-model of the RDRM model generates flow requirements using hydrology, hydraulic and the stress flow index. According to the flow sensitivity of the species that occur in the specific system, the importance of velocity depth categories are also weighted and adjusted according to specialist requirements.

2.2.2 High flows

The approach to set high flows is a combination of the Downstream Response to Imposed Flow Transformation (DRIFT; Brown and King, 2001) approach and the BBM (King and Louw, 1998). The high flows are determined as follows:

- *Flood ranges for each flood class and the riparian vegetation functions are identified and tabled by the relevant specialists.*
- *These are provided to the instream specialists who indicate:*
  - *which instream function these floods cater for;*
  - *whether additional instream functions apart from those provided are required; and*
  - *whether they require any additional flood classes to the ones identified.*
- *The number of floods for each flood class is identified as well as where (early, mid, late) in the season they should occur.*

- *The floods are evaluated by the hydrologist to determine whether they are realistic. A nearby gauge with daily data is used for this assessment. Without this information it is difficult to judge whether floods are realistic.*
- *The hydrologist then determines the daily average and documents the months in which the floods are spaced.*
- *The floods are then entered into the DRM (high flow submodel) to provide the final .rul and .tab files. This process is described below:*
  - *convert each flood to volume using specified frequency and duration*
  - *calculate total volume of all floods together for the specified category*
  - *use revised desktop model to match volume as close as possible by manipulating the following 3 variables:*

    a) No high flow when natural high flows <X% tot flows

    b) Adjust hydrological variability

    c) Maximum high flows are X% higher than normal high flows
  - *adjust variable a (above) to exclude flows (selected month) in months you do not require floods (i.e. zero volume)*
  - *adjust variable b for seasonality*
  - *adjust variable c to match calculated volume for specified category*

2.2.3 Final flow requirements

The RDRM produces a report which includes all the changes that were made to parameters by the specialists and provides the EWR rules for all ECs.

3 ECOCLASSIFICATION: MTAMVUNA RIVER (MT_R_EWR1)

3.1 EIS RESULTS

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

- *Migration route: Important for the migration of eel species in the system.*
- *Rare and Endangered riparian species: Cyathea capensis var. capensis (Declining); Gunnera perpensa (Declining); Gymnosporia bachmannii (Vulneable); Ilex mitis var. mitis (Declining); Maytenus oleosa (Rare); Prionium serratum (Declining); Syzygium pondoense (Rare).*
- *Refugia and critical riparian habitat: Refugia for above rare and endangered riparian species.*

The SQ in which the EWR site is situated is indicated as a NFEPA (National Freshwater Ecosystem Priority Area). NFEPAs have to be in an A or B EC and the detail EcoClassification process followed indicated that the river is in a C PES (see below). The SQ is therefore not a NFEPA.

3.2 PRESENT ECOLOGICAL STATE

The PES reflects the changes in terms of the EC from reference conditions. The summarised PES information is provided in Table 3.1 and water quality and diatom information is provided in Appendix A and B respectively.

Table 3.1 Mt_R_EWR1: Present Ecological State

IHI Hydrology: PES: B/C, Confidence: 3
The natural Mean Annual Runoff (nMAR) is 233.15 million cubic meters (MCM) and the Present Day MAR (pMAR) is 200.69 MCM (86.1% of the nMAR). The baseflow volumes have decreased from natural due to afforestation, alien vegetation, urban and irrigation water use. No changes in seasonality were observed for low flows and moderate and large floods have remained relatively stable.
Physico-chemical variables: PES: A/B, Confidence:3
The Mtamvuna area is a largely undeveloped catchment, with a resulting Good water quality state. Irrigation is insignificant, so little irrigation runoff is present. Water quality is therefore in an A/B category, with few impacts. Although certain data are lacking, the confidence in the assessment is estimated to be MODERATE, largely due to the simplicity of the catchment and limited land-use.
IHI Instream: PES: B/C, Confidence 2.5 IHI Riparian: PES: C, Confidence 4.2
The instream IHI is mainly impacted by decreased base flow which has led to increased sedimentation. Increased nutrient loading within the system has led to increased algal growth. *The biggest impacts on the integrity of the instream riparian area are bank structure and connectivity modification due to clearing, grazing, and the presence of alien invasive species.*
Riparian vegetation: PES: C/D, Confidence: 2.6
Marginal Zone: Narrow, dominated by reeds, sedges and grasses. *Lower Zone: Narrow steep, cobble to lateral alluvial deposits, mixture of woody and non-woody species, aliens perennials high, reeds, sedges and grasses dominant.* *Upper Zone: Narrow alluvial terraces or long gentle slope with alluvium and scattered bedrock, mixture of woody and non-woody mainly reeds and shrubs.* *Macro Channel Bank (MCB): Steep alluvium, dominated by woody vegetation, many aliens, some Combretum erythrophyllum, Ficus sur, F. sycomorus, and Erythrina lysistemon.* *Floodplain: Alluvial floodplain dominated by woody vegetation but mostly cleared for agriculture: Left bank (LB) - completely cultivated. Right bank (RB) - grass dominated with boulder and unconsolidated alluvium, high degree of woody alien cover and wood harvesting.* *Main impacts at the site are overgrazing (especially of reeds and sedges), invasion by alien perennial species (especially Sesbania punicea), wood harvesting and clearing for subsistence cultivation.*

Fish: PES: B/C, Confidence: 2
Based on the available fish distribution data and expected habitat composition, eight indigenous fish species had a high to definite probability of occurrence under reference conditions. These included two freshwater eel species (Anguilla marmorata and A. mossambica), four cyprinids (Barbus anoplus, Barbus gurneyi, Labeobarbus natalensis), and Barbus viviparous), the Sharptooth catfish (Clarias gariepinus) and one cichlid (Oreochromis mossambicus). It was estimated that all the fish species expected under natural conditions are still present in this river reach under present conditions albeit in a moderately reduced FROC. The FROC of the eels species were slightly reduced due to potential migration barriers that did not prevent migration completely but reduced the success rate of migration. Slight water quality deterioration also contributed to decreased FROC of some species (e.g. B. gurneyi) while the slight decrease in base flow, resulting in loss of habitat abundance and availability was thought to contributor for decreased FROC of some species. Reduced abundance of food sources (especially macroinvertebrates) may also have contributed slightly to the decreased FROC of some species.
Macroinvertebrates: PES: B, Confidence: 3
A total of 25 SASS5[1] taxa were recorded during the field survey in June 2012 compared to 44 expected under natural conditions. Under these conditions, the SASS score was 187 with an ASPT[2] of 7.4, which reflects a "Natural" condition. The suitability of the river for taxa with a preference for very high flows was moderate (56% of expected taxa), and for high flows was good (100% of expected taxa). These favorable conditions can be attributed to the absence of zero flows and major infrastructure and thus floods are not affected. Taxa expected but not recorded included Philopotamidae, Psephenidae and Potamonautidae. The suitability of the river for taxa with a preference for Stones-in-Current (SIC) instream habitats was good (64% of expected taxa), but riverine vegetation was low (43% of expected taxa). The lower vegetation integrity can be ascribed to vegetation clearing, alien vegetation invasion, and reeds dominate lower zones. Taxa expected but not recorded included Hydroptilidae, Pleidae, Chlorolestidae and Nepidae. The suitability of the river for taxa with a high requirement for unmodified physico-chemical conditions was good (100% of expected taxa) while there was an occurrence of 50% of the expected taxa with a preference for moderate water quality. Adverse conditions that might influence the water quality could be elevated nutrients (agriculture and rural settlements). Taxa expected but not recorded included Aeshnidae, Hydracarina, and Gerridae.

1 South African Scoring System *2 Average Score Per Taxon*

The PES EcoStatus is a C EC and the EcoStatus models are provided electronically. The major issues that have caused the change from reference condition were mainly non-flow related issues. Overgrazing, trampling, alien invasive vegetation and wood removal in the riparian zones have led to a general loss of connectivity and bank modification in the reach. The slight decrease in baseflows has impacted to some extent on habitat availability and abundance for aquatic biota while water quality impacts relating to increased nutrients also had an impact.

3.3 RECOMMENDED ECOLOGICAL CATEGORY

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability there-of. As the EIS was MODERATE no improvement was required. The REC was therefore set to maintain the PES. Due to non-flow related impacts on riparian vegetation, the EWR were set for the instream EC of a B. The EcoClassification results are summarised in Table 3.2

Table 3.2 Mt_R_EWR1: Summary of EcoClassification results

Component	PES & REC
IHI Hydrology	A/B
Physico chemical	A/B
Fish	B/C
Invertebrates	B
Instream	B
Riparian vegetation	C/D
EcoStatus	C
Instream IHI	B/C
Riparian IHI	C
EIS	MODERATE

4 EWR REQUIREMENTS: MTAMVUNA RIVER (MT_R_EWR1)

4.1 FLOW VS STRESS RELATIONSHIP

The RDRM generated a stress flow index which was reviewed and adjusted to specialist requirements. The stress flow index is provided in Figure 4.1 and a description of the habitat associated with the stress is provided in Table 4.1.

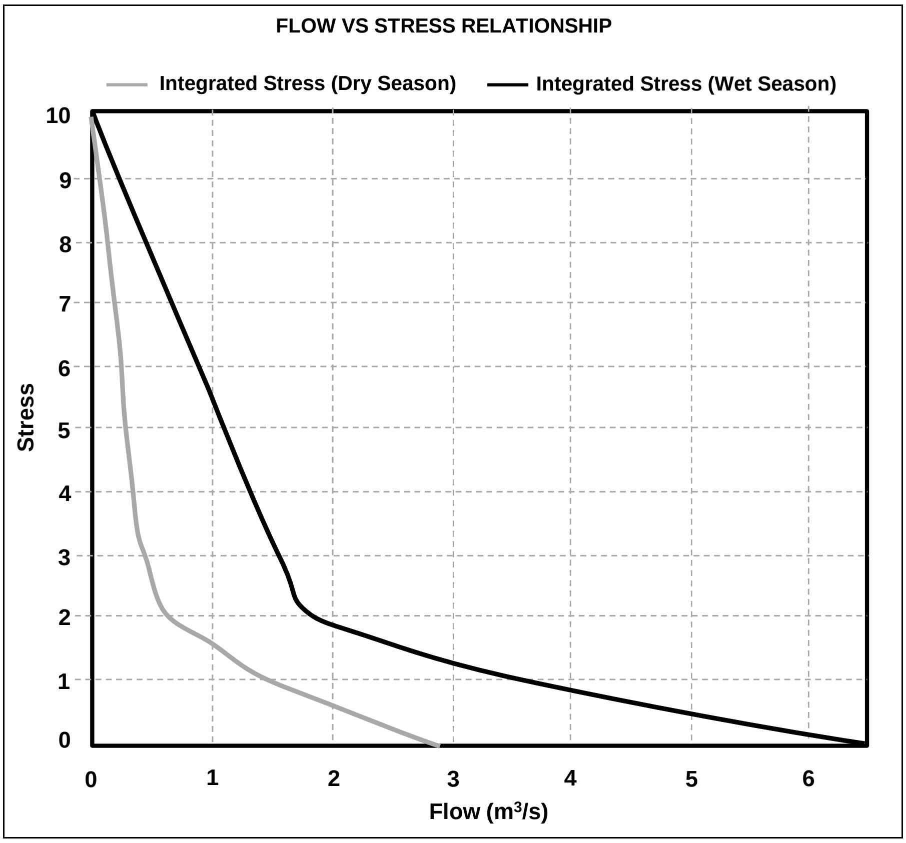

Figure 4.1 Mt_R_EWR1: Stress index

Table 4.1 Mt_R_EWR1: Integrated stress and summarised habitat/biotic responses for the dry and wet season

Stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
1	*1.395*	*Adequate fast habitats to ensure limited stress:* ▪ *11% Fast Shallow (FS).* ▪ *16% Fast Intermediate (FI).* ▪ *22% Fast Deep (FD).* ▪ *27% Fast over coarse substrate (FCS).* ▪ *9% Very fast over coarse substrate (VFCS).*	*3.486*	*Adequate fast habitats during dry season to ensure limited stress.*
5	*0.276*	*Although fast habitats are largely reduced it is adequate to maintain biota with moderate stress:* ▪ *5% FS.* ▪ *5% FI.* ▪ *0% FD.* ▪ *10% FCS.* ▪ *2% VFCS.*	*1.107*	*Slightly reduced fast habitats during wet season to resulting in moderate stress on biota:* ▪ *11% FS.* ▪ *14% FI.* ▪ *18% FD.* ▪ *25% FCS.* ▪ *8% VFCS.*

Stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
8	*0.110*	*Limited FS (4%) and FCS (6%) but no FI, FD and VFCS, resulting in very high stress on instream biota.*	*0.443*	*Largely reduced fast habitats resulting in high stress on biota:* ▪ *7% FS.* ▪ *6% FI.* ▪ *2% FD.* ▪ *13% FCS.* ▪ *3% VFCS.*

4.2 STRESS WEIGHTINGS

The parameters provided in Table 4.2 are the only option to adjust the requirements according to the sensitivity of instream biota to velocity-depth classes. There parameters are explained below:

- *Stress at 0 discharge for FS: This represents the stress at zero fast-shallow flow, i.e. the stress when there is no modelled velocity in the channel less than 0.3 m/s. (Note, the stress at zero flow or discharge is by default a 10).*
- *Weight of velocity-depth classes: The importance of the FS, FI and FD velocity depth categories must be ranked according to which category is most important (i.e. the highest weight is assigned to the most important category). The importance is based on the flow sensitivity of the species that occur and differs between the wet and dry season. The weightings provided are relative to each other.*

Table 4.2 Mt_R_EWR1: Stress weightings

Parameters	Dry stress	Motivation	Wet stress	Motivation
Stress at 0 FS	*9*	*During dry season some rheophilic macroinvertebrate taxa (5 out of an expected 8 taxa present) need fast flows to maintain their ecological needs. Fish has a lower requirement for fast habitats during the dry season due to only semi-rheophilic species being present.*	*9*	*Large semi-rheophilic species (L. natalensis) require fast flows during the wet season for spawning habitat. Fast habitats are also required to provide feeding grounds for juvenile eels. Loss of flow will also reduce water quality (especially oxygen) that is required to maintain habitat quality (especially nursery areas for larvae). Loss of fast habitats will also be detrimental to rheophilic macroinvertebrate taxa.*
Parameters	**Weight**	**Motivation**	**Weight**	**Motivation**
FS	*3*	*Fast shallow habitats over stones are adequate to maintain the macroinvertebrate assemblage during the dry season (maintenance of deeper habitats therefore of lower importance).*	*1*	*It is more important to maintain deeper habitats (FI and FD) than FS as large semi-rheophilic fish species are present (requirement for deeper fast habitats).*
FI	*2*		*2*	
FD	*1*		*2*	

4.3 INSTREAM BIOTA REQUIREMENTS

The RDRM generates the stress (and flow) requirements for different ECs. Once specialists are satisfied that these results (Figure 4.2) are adequate to maintain the river at the appropriate EC, descriptions are provided for key stress points (Table 4.3)

Table 4.3 Mt_R_EWR1: Stress requirements and habitat and instream biota description

PES: B	Dry season		Wet season	
Percentile	**Flow (m^3/s)**	**Description**	**Flow (m^3/s)**	**Description**
95% (drought)	*0.375*	*Biota will be notably stressed but flow should be adequate to allow survival and ensure maintenance in PES:* ▪ *6% FS.* ▪ *6% FI.* ▪ *1% FD.* ▪ *11% FCS.* ▪ *2% VFCS.*	*1.62*	*Adequate fast habitats (abundance and diversity) will be maintained even under drought conditions:* ▪ *8% FS.* ▪ *16% FI.* ▪ *27% FD.* ▪ *27% FCS.* ▪ *12% VFCS.*
70%	*0.59*	*Adequate to maintain the biota in PES:* ▪ *10% FS.* ▪ *9% FI.* ▪ *6% FD.* ▪ *17% FCS.* ▪ *5% VFCS.*	*2.29*	*Adequate fast habitats to maintain biota (especially for large semi-rheophilic species (L. natalensis)) in healthy state:* ▪ *7% FS.* ▪ *16% FI.* ▪ *41% FD.* ▪ *27% FCS.* ▪ *19% VFCS.*

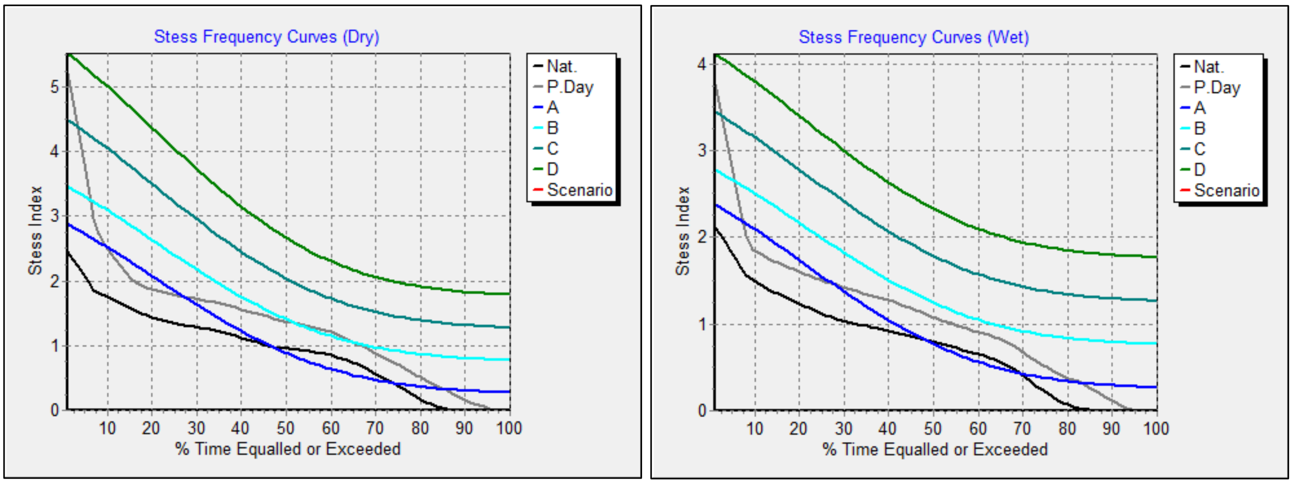

Figure 4.2 Mt_R_EWR1: Stress frequency curves for the dry and wet season

4.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

The low flow EWR was checked by the riparian vegetation specialist to ensure that these requirements were adequate for the marginal and any other flow dependant vegetation to achieve the EC. At this site the vegetation indicator used was Phragmites australis and these reeds activate at 0.5m^3/s. The low flow requirements for the instream B EC was analysed to determine how often the reeds will be activated at 0.5 m^3/s. The results showed that on the flow duration table, reeds were activated almost all the time. Low flows that were specified will maintain some inundation (up to 20 cm) of marginal zone reeds (and other vegetation in the zone) throughout summer, with sufficient activation during winter months to ensure water availability for survival.

4.5 HIGH FLOW REQUIREMENTS

The high flow classes were identified as follows:

- *The riparian vegetation specialist identified the range of flood classes required and listed the functions of each flood.*

- *The instream specialists then indicated which of the instream flooding functions were addressed by the floods identified for geomorphology and riparian vegetation (indicated by a ✓ in 4).*
- *Any of the floods required by the instream biota and not addressed by the floods already identified, were then described (in terms of ranges and functions) for the instream biota.*

Detailed motivations are provided in Table 4.4 and final high flow results are provided in No reliable gauges were present in the reach and therefore the RDRM flood function was used to verify high flows.
Table 4.55.

Table 4.4 Mt_R_EWR1: Identification of instream functions addressed by the identified floods for riparian vegetation

		Fish flood functions						**Macroinvertebrate flood functions**			
Flood Class Flood Range (Peak in m³/s)	**Riparian vegetation motivation**	**Migration cues & spawning**	**Migration habitat (depth etc.)**	**Clean spawning substrate**	**Create nursery areas**	**Resetting water quality**	**Inundate vegetation for spawning**	**Breeding and hatching cues**	**Clear fines**	**Scour substrate**	**Reach or inundate specific areas**
CLASS I (6 – 8)	*Required to inundate marginal zone vegetation.* ▪ *Prevents establishment of terrestrial or some alien species in the marginal zone.* ▪ *Provides recruitment opportunities in the marginal and lower zones.* ▪ *Stimulates growth and reproduction.* ▪ *Prevents encroachment of marginal zone vegetation towards the channel.* ▪ *Specifically at the site these flows activate marginal zone sedges and floods about 50% of the reed and Persicaria populations.*	√	√	√	√	√	√	√	√		√
CLASS II (17 - 25)	*Generally the same function as above. At the site these flows flood Cyperus longus, Persicaria sp., about 75% of the reed population and about 50% of the Juncus population.*	√	√	√	√	√	√	√	√		√
CLASS III (32 - 40)	*Required to inundate lower zone vegetation and activate upper zone vegetation. Similar functions to above in these zones.* ▪ *Maintains heterogeneity in the marginal zone.* ▪ *Floods reeds to upper limit of the population, i.e. C. dives and Ludwigia.*	√	√	√	√	√	√			√	√
CLASS IV (50 - 80)	*Floods Ficus sur and Juncus spp. populations. Provides recruiting opportunities, increases the probability of survival of current year seedling through the oncoming dry season, and moves propagules (hydrochory).*	√	√	√	√	√	√			√	√
CLASS V (≥ 150)	*Required to elicit recruiting opportunities for Combretum erythrophyllum: Samaras from the previous season lie in the leaf litter and wetting by floods (or rainfall) will promote germination on site or in other areas where hydrochory takes place.* ▪ *Scours the marginal and lower zones preventing sediment build up and reed or sedge encroachment.* ▪ *Prevents/reduces terrestrialisation of lower and upper zones.*	√	√	√	√	√	√			√	

No reliable gauges were present in the reach and therefore the RDRM flood function was used to verify high flows.

Table 4.5 Mt_R_EWR1: The recommended number of high flow events required

Flood Class (Peak in m^3/s)	Flood requirements*	Months	Daily Ave.	Duration (days)
CLASS I (6 – 8)	6	Growing season (spring to summer)	6	3
CLASS II (17 - 25)	4	Late summer (Feb - Mar)	18	4
CLASS III (32 - 40)	1	December	32	6
CLASS IV (50 - 80)	1:2		50	
CLASS V (≥ 150)	1:3-5		150	

*Refers to frequency of occurrence per year, i.e. how often will the flood occurs per year.

4.6 EWR RESULTS

The results are provided as an EWR table (Table 4.6) and an EWR rule (Table 4.7). Detailed results are provided in the model generated report for each category in Appendix C.

The low flow EWR rule table is useful for operating the system, whereas the EWR table must be used for operation of high flows. A summary of the results is provided in Table 4.8.

Table 4.6 Mt_R_EWR1: EWR table for Instream PES and REC: B

Month	Low Flows			High Flows (m^3/s)	
	Drought (90%) (m^3/s)	70% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
Oct	1.594	4.316	6.666	6	3
Nov	2.403	6.403	9.476	6 18	3 4
Dec	2.71	7.303	11.394	6 18 32	3 4 6
Jan	2.935	7.859	11.982	6 18	3 4
Feb	3.198	7.564	11.049	6 18	3 4
Mar	4.514	8.296	11.768	6 18	3 4
Apr	3.79	6.799	9.889		
May	3.308	3.789	6.47		
Jun	1.769	2.298	4.523		
Jul	1.341	1.689	3.536		
Aug	1.365	1.707	2.939		
Sep	0.996	1.523	2.861		

Table 4.7 Mt_R_EWR1: Assurance rules (m^3/s) for Instream PES and REC: B

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	15.344	12.416	9.871	8.091	6.666	5.658	4.316	2.984	1.594	1.5
Nov	23.596	18.355	14.262	11.541	9.476	8.237	6.403	4.386	2.403	2.336
Dec	25.03	19.994	16.21	13.457	11.394	9.454	7.303	4.97	2.71	2.646
Jan	24.619	20.373	17.093	14.203	11.982	10.259	7.859	5.313	2.935	2.874
Feb	23.231	19.032	15.282	12.978	11.049	9.599	7.564	5.265	3.198	3.136
Mar	22.812	19.197	16.046	13.387	11.768	10.37	8.296	6.169	4.514	4.3

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Apr	*17.992*	*14.975*	*13.31*	*11.262*	*9.889*	*8.627*	*6.799*	*4.985*	*3.79*	*2.962*
May	*9.665*	*8.361*	*7.588*	*7.246*	*6.47*	*5.181*	*3.789*	*3.31*	*3.308*	*3.206*
Jun	*7.491*	*5.747*	*5.606*	*5.257*	*4.523*	*3.405*	*2.298*	*1.769*	*1.769*	*1.703*
Jul	*5.859*	*5.052*	*4.865*	*4.517*	*3.536*	*2.624*	*1.689*	*1.352*	*1.341*	*1.092*
Aug	*5.495*	*4.717*	*4.174*	*3.645*	*2.939*	*2.296*	*1.707*	*1.365*	*1.365*	*1.091*
Sep	*4.338*	*4.137*	*3.771*	*3.365*	*2.861*	*2.182*	*1.523*	*1.251*	*0.996*	*0.789*

Table 4.8 Mt_R_EWR1: Summary of results as a percentage of the nMAR

EWR site	PES & REC	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
Mt_R_EWR1	*Instream: B*	*233.15*	*200.69*	*60.99*	*26.20*	*35.08*	*15.00*	*96.07*	*41.20*

5 ECOCLASSIFICATION: LOVU RIVER (LO_R_EWR1)

5.1 EIS RESULTS

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

- *Diversity of habitat types and features: Overhanging vegetation, backwaters, pools and riffles.*
- *Migration route: Migration of eel species and macroinvertebrates.*
- *Rare and Endangered riparian species: Vulnerable Crinum moorei.*

5.2 PRESENT ECOLOGICAL STATE

The PES reflects the changes in terms of the EC from reference conditions. The summarised PES information is provided in Table 5.1 and water quality and diatom information is provided in Appendix A and B respectively.

Table 5.1 Lo_R_EWR1: Present Ecological State

IHI Hydrology: PES: B/C, Confidence: 3
The nMAR is 87.76 MCM and the present pMAR is 73.42 MCM (83.6% of the nMAR). The baseflow volumes have decreased from natural due to afforestation, alien vegetation, small dams, urban and irrigation water use. No changes in seasonality were observed for low flows and moderate and large floods have remained relatively stable.
Physico-chemical variables: PES: B/C, Confidence:3
Sugarcane plantations (irrigation) and forestry (afforestation), including informal cattle farming, are the predominant land uses in the Lovu catchment, with Richmond and Amanzimtoti representing the main urban land use areas. Two of the smaller Mgwahumbe catchments are however still largely natural. E. coli, phosphates (SRP, i.e. Soluble Reactive Phosphate) and turbidity are problematic in the catchment, which is probably due to livestock farming, intensive sugarcane farming sand mining and inefficient Waste Water Treatment Works (WWTWs). Although certain data are lacking, the confidence in the assessment is estimated to be moderate, largely due to the simplicity of the catchment and limited land-use.
IHI Instream: PES: B/C, Confidence 2.5 IHI Riparian: PES: B/C, Confidence 3.5
The instream IHI is mainly impacted by decreased baseflow due to upstream land use which includes forestry and sugarcane farming. The presence of dams and the land use has led to increased sedimentation within the system and increased nutrient loading which has led to increased algal growth. *The biggest impact on the integrity of the instream riparian area is non-marginal alien invasive species.*
Riparian vegetation: PES: B/C, Confidence: 3
Marginal Zone: Dominated by sedges, reeds and grasses especially Cyperus dives and LM grass. *Lower Zone: Dominated by sedges especially C. dives.* *Upper Zone: Mix of woody and non-woody vegetation - sedges and grass; mostly young figs and Acacia gerardii.* *MCB: Woody, with high density of aliens and terrestrial species.* *Backwaters: Backwater with an aquatic component, water lilies and sedges.* *Main impacts at the site are grazing/trampling (low impacts to sedges and woody seedlings), and invasion by alien species (mainly S. punicea and Wattle). Some wood harvesting was also noted.*
Fish: PES: B/C, Confidence: 2
Based on the available fish distribution data and expected habitat composition, twelve indigenous fish species are expected under reference conditions. These include three freshwater eel species (A. bicolor bicolor, A. bengalensis and A. mossambica), three cyprinids (B. gurneyi, L. natalensis, and B. viviparous), the sharptooth catfish (C. gariepinus), two cichlids (O. mossambicus and Tilapia sparrmanii), one goby (Awaous aenofuscus), a moony (Monodactyus argenteus) and a mullet (Myxus capensis). The presence of eight of the expected species was confirmed during a survey conducted in August 2013. Based on all available information it is estimated that all the fish species expected under natural conditions are still present in this river reach under present conditions albeit in a moderately reduced FROC. Slight water quality deterioration contributed to potential decreased FROC of species with intolerance to physico-chemical alteration (such as B. gurneyi) while the slight decrease in base flow, resulting in loss of habitat abundance and availability was thought to contributor for decreased FROC of species with a preference for fast habitats (L. natalensis). Increased sedimentation due to overgrazing and erosion in the catchment also reduced the FROC of species with a preference for substrate as cover (L. natalensis). Alteration in the condition and availability of the marginal zone (overhanging vegetation) decreased the FROC of species with a preference for this cover type (T. sparrmanii and B. gurneyi). Slight reduced abundance of food sources (especially macroinvertebrates) may also have

contributed slightly to the decreased FROC of some species.
Macroinvertebrates: PES: B/C, Confidence: 2
A total of 27 SASS5 taxa were recorded during the field survey in June 2012 compared to 63 expected under natural conditions. Under these conditions, the SASS score was 170 with an ASPT of 6.3, which reflects a "Good" condition. The suitability of the river for taxa with a preference for very high flows was low (30% of expected taxa), and for high flows was good (78% of expected taxa). These conditions can be attributed to the upstream dam that regulates flows and somewhat affects floods. Taxa expected but not recorded included Oligoneuridae, Prosopistomatidae, Psephenidae, Tricorythidae and Philopotamidae. The suitability of the river for taxa with a preference for SIC instream habitats was moderate (53% of expected taxa), but riverine vegetation was very low (11% of expected taxa). The vegetation integrity was relatively high, thus the lower scores in this habitat might be ascribed to water quality impacts in this biotope, overgrazing and sediment build-up in the backwaters. Eighteen taxa were expected in the vegetation biotope but only two were recorded. The suitability of the river for taxa with a high requirement for unmodified physico-chemical conditions was moderate (50% of expected taxa), and moderate conditions was low (37% of expected taxa). Adverse conditions that might influence the water quality could be elevated nutrients (sugar cane, fertilizers, storm water, waste water and cattle) and sand mining (sedimentation). Taxa expected but not recorded included Pyralidae, Elmidae, Chlorocyphidae and Ecnomidae.

The PES EcoStatus is a B/C EC and the EcoStatus models are provided electronically. Flow related impacts are mainly related to reduced base flows due to dams and general landuse in the upper catchment which includes forestry and sugarcane farming. Non-flow-related issues include deteriorated water quality and increased sedimentation due to livestock farming, WWTW, sand mining and sugarcane farming. Alien invasive vegetation and wood removal in the riparian zones also impact the reach.

5.3 RECOMMENDED ECOLOGICAL CATEGORY

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability there-of. As the EIS was MODERATE no improvement was required. The REC was therefore set to maintain the PES. The final EcoClassification results are summarised in Table 5.2.

Table 5.2 Lo_R_EWR1: Summary of EcoClassification results

Component	PES & REC
IHI Hydrology	B
Physico chemical	B/C
Fish	B/C
Invertebrates	B/C
Instream	B/C
Riparian vegetation	B/C
EcoStatus	B/C
Instream IHI	B/C
Riparian IHI	B/C
EIS	MODERATE

6 EWR REQUIREMENTS: LOVU RIVER (LO_R_EWR1)

6.1 FLOW VS STRESS RELATIONSHIP

The RDRM generated a stress flow index which was reviewed and adjusted to specialist requirements. The stress flow index is provided in Figure 6.1 and a description of the habitat associated with the stress is provided in Table 6.1.

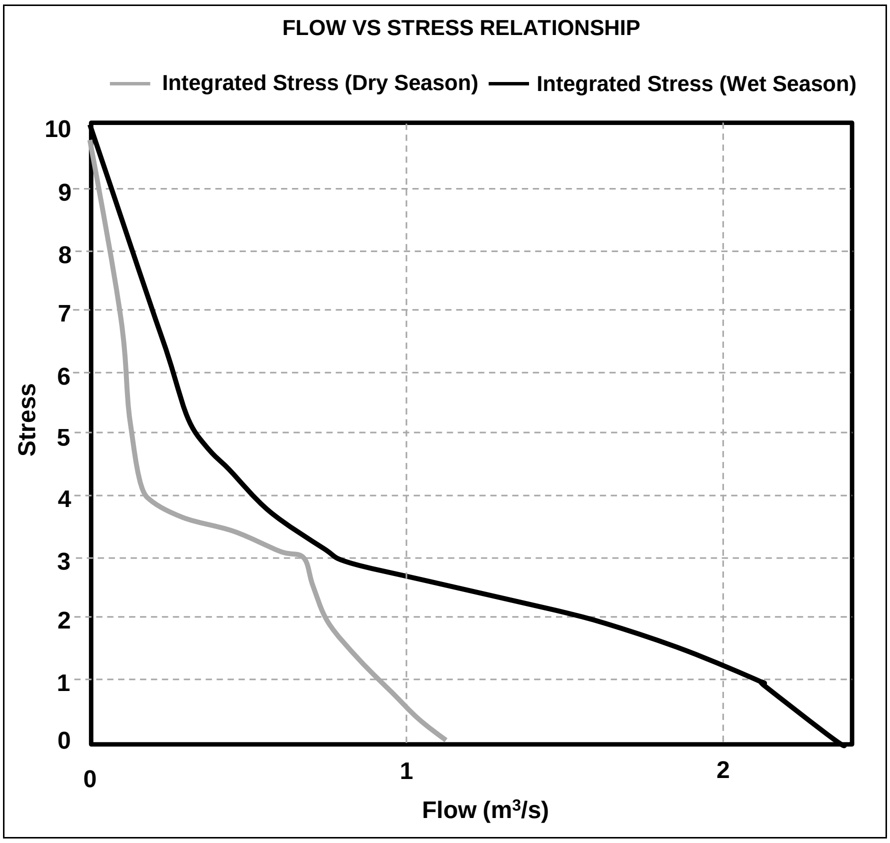

Figure 6.1 Lo_R_EWR1: Stress index

Table 6.1 Lo_R_EWR1: Integrated stress and summarised habitat/biotic responses for the dry and wet season

Stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
2	*0.9*	*Adequate fast habitats ensure limited stress:* ▪ *8% FS.* ▪ *11% FI.* ▪ *26% FD.* ▪ *26% FCS.* ▪ *9% VFCS.*	*2.2*	*Adequate fast habitats ensure limited stress.*
5	*0.14*	*Very limited fast habitats available, adequate to maintain biota with moderate stress:* ▪ *8% FS.* ▪ *1% FI.* ▪ *0% FD.* ▪ *8% FCS.* ▪ *1% VFCS.*	*0.33*	*Slightly reduced fast habitats during wet season resulting in moderate stress on biota:* ▪ *8% FS.* ▪ *13% FI.* ▪ *0% FD.* ▪ *14% FCS.* ▪ *4% VFCS.*
8	*0.054*	*All fast habitats will be lost, resulting in*	*0.13*	*Largely reduced fast habitats*

Stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
		serious stress on instream biota.		*resulting in high stress on biota:* ▪ *8% FS.* ▪ *1% FI.* ▪ *0% FD.* ▪ *8% FCS.* ▪ *1% VFCS.*

6.2 STRESS WEIGHTINGS

The stress weightings are provided in Table 6.2.

Table 6.2 Lo_R_EWR1: Stress weightings

Parameters	Dry stress	Motivation	Wet stress	Motivation
Stress at 0 FS	*9*	*Some rheophilic macroinvertebrate taxa need fast flows to maintain their ecological integrity, driven by habitat and water quality. Fish has a lower requirement for fast habitats during the dry season due to only semi-rheophilic species being present.*	*9*	*Large semi-rheophilic species (L. natalensis) require fast flows during the wet season for spawning habitat. Fast habitats are also required to provide feeding grounds for juvenile eels. Loss of flow will also reduce water quality (especially oxygen) which is required to maintain habitat quality (especially nursery areas for larvae). Loss of fast habitats will also be detrimental to rheophilic macroinvertebrate taxa.*
Parameters	**Weight**	**Motivation**	**Weight**	**Motivation**
FS	*1*	*A good mix of viable habitats in fast flows over stones is favourable to maintain the macroinvertebrate assemblage during the dry season.*	*3*	*It is more important to maintain deeper habitats (FI and FD) than FS as large semi-rheophilic fish species are present (requirement for deeper fast habitats).*
FI	*1*		*4*	
FD	*1*		*5*	

6.3 INSTREAM BIOTA REQUIREMENTS

The RDRM generates the stress (and flow) requirements for different ECs. Once specialists are satisfied that these results (Figure 6.2) are adequate to maintain the river at the appropriate EC, descriptions are provided for key stress points (Table 6.3)

Table 6.3 Lo_R_EWR1: Stress requirements and habitat and biota description

PES: B	Dry season		Wet season	
Percentile	Flow (m^3/s)	Description	Flow (m^3/s)	Description
95% (drought)	*0.143*	*Biota will be notably stressed but flow should be adequate to allow survival and ensure maintenance of aquatic population in PES:* ▪ *8% FS.* ▪ *1% FI.* ▪ *0% FD.* ▪ *8% FCS.* ▪ *1% VFCS.*	*0.39*	*Although the biota will be somewhat stressed (no FD habitats), adequate fast habitats (abundance and diversity) will be maintained:* ▪ *8% FS.* ▪ *15% FI.* ▪ *1% FD.* ▪ *16% FCS.* ▪ *4% VFCS.*
70%	*0.25*	*Although thought to be relatively low (high stress), it should be adequate to maintain the biota in the PES:* ▪ *10% FS.* ▪ *6% FI.* ▪ *0% FD.* ▪ *12% FCS.*	*0.61*	*Adequate fast habitats to maintain biota (especially for large semi-rheophilic species (L. natalensis)) in healthy state:* ▪ *6% FS.* ▪ *17% FI.* ▪ *10% FD.* ▪ *22% FCS.*

PES: B	Dry season		Wet season	
Percentile	Flow (m^3/s)	Description	Flow (m^3/s)	Description
		▪ *2% VFCS.*		▪ *6% VFCS.*

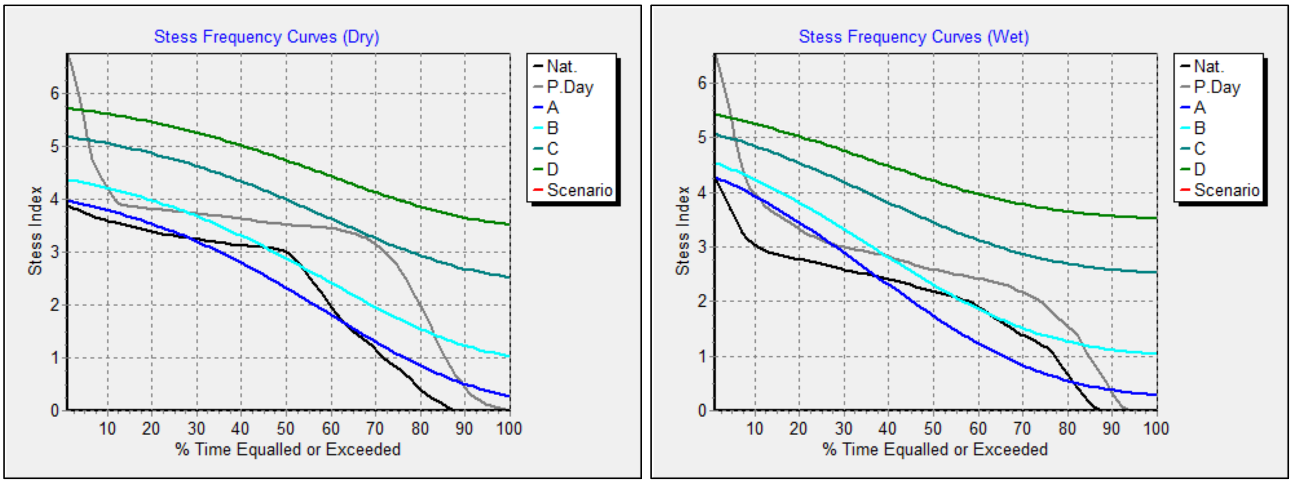

Figure 6.2 Lo_R_EWR1: Stress frequency curves for the dry and wet season

6.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

The above flows were checked by the riparian vegetation specialist to ensure that these requirements were adequate for the marginal and any other flow dependant vegetation to achieve the EC. At this site the vegetation indicator used was Phragmites australis which activate at 0.3 m^3/s. The % time that reeds are activated in each month by the flows specified for the B/C EC are provided in Table 6.4.

Table 6.4 Lo_R_EWR1: % time that reeds are activated at a discharge of 0.3 m^3/s

Month	% time that reeds are activated
Oct	50
Nov	50
Dec	60
Jan	90
Feb	90
Mar	100
Apr	100
May	100
Jun	70
Jul	50
Aug	50
Sep	50

Low flows that were specified will generally maintain inundation (up to 11 cm) of marginal zone reeds (and other vegetation in the zone such as Setaria) throughout summer, with sufficient activation during winter months to ensure water availability for survival. Sedges do not generally get inundated and range from 10 cm to 1 m above the water level. Water stress may be evident but high flows are important to survival in the dry season and growth and reproductive success in the wet season.

6.5 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in Table 6.5 and final high flow results are provided in Table 6.6.

Table 6.5 Lo_R_EWR1: Identification of instream functions addressed by the identified floods for riparian vegetation

Flood Class Flood Range (Peak in m^3/s)	Riparian vegetation motivation	Fish flood functions						Macroinvertebrate flood functions			
		Migration cues & spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
CLASS I (2.5 – 10)	*Required to inundate marginal and lower zone vegetation.* ▪ *Prevents establishment of terrestrial or some alien species in the marginal zone.* ▪ *Provides recruitment opportunities in the marginal and lower zones.* ▪ *Stimulates growth and reproduction.* ▪ *Prevents encroachment of marginal zone vegetation towards the channel.* ▪ *Specifically at the site the flows flood marginal and lower zone reed and hydrophilic grasses and inundate about 50% of the sedge population.*	√	√	√	√	√	√	√	√		√
CLASS II (10 - 25)	*Generally the same function as above. At the site these flows activate and partially flood the Eleocharis and Ficus sur (especially saplings) populations. The sedge population is completely flooded and replenishes backwaters and secondary channels.*	√	√	√	√	√	√	√	√		√
CLASS III (25 - 35)	*Required to inundate lower zone vegetation and activate upper zone vegetation. Similar functions to above in these zones. Maintains heterogeneity in the marginal zone and activates the shrub layer.*	√	√	√	√	√	√			√	√
CLASS IV (50 - 90)	*Floods the macro channel up to the tree line and prevents terrestrialisation.*	√	√	√	√	√	√			√	

Table 6.6 Lo_R_EWR1: The recommended number of high flow events required

Flood Class (Peak in m^3/s)	Flood requirements*	Months	Daily Ave.	Duration (days)
CLASS I (2.5 – 10)	*4*	*Growing season (spring to summer). At least one late spring/early summer for fish.*	*2.5*	*3*
CLASS II (10 - 25)	*2*	*Summer.*	*10*	*4*
CLASS III (25 - 35)	*1*	*Late summer (Feb - Mar).*	*25*	*6*
CLASS IV (50 - 90)	*1:3**		*50*	

**Refers to frequency of occurrence per year, i.e. how often will the flood occurs per year.*

6.6 EWR RESULTS

The results are provided as an EWR table (Table 6.7) and an EWR rule (Table 6.8). Detailed results are provided in the model generated report for each category in Appendix C.

The low flow EWR rule table is useful for operating the system, whereas the EWR table must be used for operation of high flows. A summary of the results is provided in Table 6.9.

Table 6.7 Lo_R_EWR1: EWR table for PES and REC: B/C

Month	Low Flows			High Flows (m^3/s)	
	Drought (90%) (m^3/s)	70% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
Oct	*0.180*	*0.376*	*0.683*		
Nov	*0.215*	*0.620*	*1.024*	*2.5*	*3*
Dec	*0.249*	*0.649*	*1.075*	*10*	*4*
Jan	*0.312*	*0.875*	*1.315*	*2.5*	*3*
Feb	*0.373*	*1.207*	*1.673*	*2.5* *10*	*3* *4*
Mar	*0.413*	*1.051*	*1.430*	*2.5* *25*	*3* *6*
Apr	*0.367*	*0.859*	*1.194*		
May	*0.329*	*0.478*	*0.712*		
Jun	*0.263*	*0.348*	*0.583*		
Jul	*0.188*	*0.222*	*0.482*		
Aug	*0.161*	*0.163*	*0.416*		
Sep	*0.144*	*0.247*	*0.502*		

Table 6.8 Lo_R_EWR1: Assurance rules (m^3/s) for PES and REC: B/C

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	*1.591*	*1.256*	*1.082*	*0.903*	*0.683*	*0.469*	*0.376*	*0.294*	*0.180*	*0.162*
Nov	*2.850*	*1.936*	*1.530*	*1.268*	*1.024*	*0.802*	*0.620*	*0.446*	*0.215*	*0.206*
Dec	*3.056*	*2.164*	*1.627*	*1.341*	*1.075*	*0.831*	*0.649*	*0.470*	*0.249*	*0.240*
Jan	*3.544*	*2.651*	*2.017*	*1.589*	*1.315*	*1.077*	*0.875*	*0.619*	*0.312*	*0.228*
Feb	*4.611*	*3.353*	*2.542*	*2.029*	*1.673*	*1.464*	*1.207*	*0.834*	*0.373*	*0.306*
Mar	*3.651*	*2.771*	*2.176*	*1.754*	*1.430*	*1.284*	*1.051*	*0.760*	*0.413*	*0.343*
Apr	*2.905*	*2.277*	*1.799*	*1.468*	*1.194*	*1.041*	*0.859*	*0.636*	*0.367*	*0.289*
May	*1.264*	*1.187*	*1.092*	*0.957*	*0.712*	*0.583*	*0.478*	*0.436*	*0.329*	*0.109*
Jun	*1.019*	*0.986*	*0.949*	*0.808*	*0.583*	*0.414*	*0.348*	*0.301*	*0.263*	*0.072*
Jul	*0.876*	*0.782*	*0.768*	*0.672*	*0.482*	*0.286*	*0.222*	*0.202*	*0.188*	*0.075*

Aug	*0.803*	*0.728*	*0.674*	*0.604*	*0.416*	*0.230*	*0.163*	*0.162*	*0.161*	*0.071*
Sep	*1.120*	*0.956*	*0.851*	*0.712*	*0.502*	*0.303*	*0.247*	*0.201*	*0.144*	*0.132*

Table 6.9 Lo_R_EWR1: Summary of results as a percentage of the nMAR

EWR site	PES & REC	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
Lo_R_EWR1	*B/C*	*87.76*	*73.42*	*20.04*	*22.80*	*13.19*	*15.10*	*33.23*	*37.90*

7 ECOCLASSIFICATION: uMNGENI RIVER (MG_R_EWR1)

7.1 EIS RESULTS

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

- *Diversity of habitat types and features: Included pools and riffles with some habitat being sensitive to water quality changes.*
- *Rare and endangered riparian species: Gymnosporia bachmannii (Vulnerable).*

The SQ in which the EWR site is situated is indicated as a NFEPA (National Freshwater Ecosystem Priority Area). NFEPAs have to be in an A or B EC and the detail EcoClassification process followed indicated that the river is in a C/D PES (see below). The EIS is also LOW. Furthermore, reasoning providing for the NFEPA also only indicated an extremely commong fish species. The SQ is therefore not a NFEPA.

7.2 PRESENT ECOLOGICAL STATE

The PES reflects the changes in terms of the EC from reference conditions. The summarised PES information is provided in Table 7.1 and water quality and diatom information is provided in Appendix A and B respectively.

Table 7.1 Mg_R_EWR1: Present Ecological State

IHI Hydrology: PES: C, Confidence: 3
The nMAR is 79.22 MCM and the pMAR is 60.46 MCM (76.3% of the nMAR). The baseflow volumes have decreased from natural due to afforestation and irrigation water use. No changes in seasonality were observed for low flows and moderate and large floods have remained relatively stable.
Physico-chemical variables: PES: B, Confidence:3
Water quality upstream of Midmar Dam is in a relatively good state, with the main water quality impacts being agricultural runoff and livestock farming. The confidence was moderate as no reference condition data were available for use. There is moderate to high confidence in the present state data, although little data exists for toxics.
IHI Instream: PES: C, Confidence 2.5 IHI Riparian: PES: C, Confidence 4.2
The instream IHI is mainly impacted by decreased baseflow due to irrigation and farm dams. Longitudinal connectivity is impacted by various weirs in the system and especially by Nagle, Midmar, Albert Falls and Inanda dams. The riparian integrity is impacted largely by the presence of alien invasive vegetation in the non-marginal zone which impacts connectivity as well.
Riparian vegetation: PES: C/D, Confidence: 2.9
Marginal Zone: Narrow zone dominated by sedges, grasses and includes the woody rheophyte Gomphostigma virgatum. *Lower Zone: Similar to marginal zone but with Salix fragilis where alluvium exists and Cliffortia nitidula where alluvial banks are steep at the water's edge (near vertical).* *Upper Zone: Steep, dominated by woody vegetation mostly, but with some grassed areas. Woody species are dominated by alien species, Bramble, Poplar, Wattle and Crack Willow.* *MCB: Steep, mainly grassland areas with seeps. Invasion by Wattle and Bramble is high.* *Main impacts at the site are reduced base flows and floods that facilitate an increase in non-woody vegetation as well as aliens such as Brambles. Invasion by alien plant species is high, notably Bramble and Wattle and clearing on the banks evident in places.*
Fish: PES: D, Confidence: 2
Based on the available fish distribution data and expected habitat composition only four indigenous fish species are expected under reference conditions (A. mossambica, A. natalensis, B. anoplus and L. natalensis). The presence of only one of these species, namely L. natalensis was confirmed during a survey conducted in August 2013. Based on all available information it is estimated that all the fish species expected under natural conditions are still present in this river reach under present conditions albeit in a largely reduced FROC. The most significant impact is estimated to be related to the presence of aggressive predatory alien fish species (Micropterus salmoides, Micropterus dolomieu and Salmo trutta). The presence of M. dolomieu was also confirmed during the August 2013 survey. Slight water quality deterioration may have contributed slightly to potential decreased FROC of species with intolerance to physico-chemical alteration (such as A. natalensis and L. natalensis). A decrease in base flow, resulting in loss of habitat abundance and availability was thought to contributor for decreased FROC of species with a preference for fast habitats (A. natalensis and L. natalensis). Alteration in the condition and availability of the marginal zone (overhanging vegetation) decreased

the FROC of species with a preference for this cover type (B. anoplus). Reduced abundance of food sources (especially macroinvertebrates) may also have contributed slightly to the decreased FROC of some species. The presence of migration barriers (especially large downstream dams) resulting in decreased migration success of especially the catadromous eel (A. mossambica), as well as potadromous L. natalensis.
Macroinvertebrates: PES: C, Confidence: 2
A total of 20 SASS5 taxa were recorded during the field survey in June 2012 compared to 54 expected under natural conditions. Under these conditions, the SASS score was 102 with an ASPT of 5.1, which reflects a "Fair" condition. The suitability of the river for taxa with a preference for very high flows was low (44% of expected taxa), and for high flows was also low (30% of expected taxa). These conditions can be attributed to dams in the system, a weir at the site and decreased baseflows. Taxa expected but not recorded included Oligoneuridae, Prosopistomatidae, Psephenidae, Heptageniidae and Philopotamidae. The suitability of the river for taxa with a preference for SIC instream habitats was moderate-low (45% of expected taxa) due to a decrease in base flow, but riverine vegetation was low (29% of expected taxa). The vegetation integrity was relatively moderate, thus the lower vegetation integrity can be ascribed to vegetation clearing, overgrazing and alien invaders. Taxa expected in the vegetation biotope but not recorded included Pyralidae, Hydraenidae, Platycnemidae, Hydroptilidae, Pleidae, Chlorolestidae, and Belostomatidae. The suitability of the river for taxa with a high requirement for unmodified physico-chemical conditions was low (29% of expected taxa), and moderate conditions was very low (11% of expected taxa). Adverse conditions that might influence the water quality could be: high sediment transport, low oxygen values, toxins and changes in pH. Taxa expected but not recorded included Perlidae, Philopotamidae, Elmidae, Chlorocyphidae and Ecnomidae.

The PES EcoStatus is a C/D EC and the EcoStatus models are provided electronically. The major non-flow related impacts are aggressive alien fish species and exotic vegetation species. There is some decrease in base flows due to abstractions for agriculture.

7.3 RECOMMENDED ECOLOGICAL CATEGORY

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability there-of. As the EIS was LOW no improvement was required. The C/D PES is mainly due to non-flow related impacts and not representative of flow related problems in the reach. It was decided to exclude alien fish species from the assessment resulting in a PES of a C EC for fish and an instream PES of a C EC for which flow requirements were set. The final EcoClassification results are summarised Table 7.2.

Table 7.2 MG_R_EWR1: Summary of EcoClassification results

Component	PES & REC
IHI Hydrology	B
Physico chemical	B
Fish	D (C)
Invertebrates	C
Instream	C/D (C)
Riparian vegetation	C/D
EcoStatus	C/D
Instream IHI	C
Riparian IHI	C
EIS	LOW

8 EWR REQUIREMENTS: uMNGENI RIVER (MG_R_EWR1)

8.1 FLOW VS STRESS RELATIONSHIP

The RDRM generated a stress flow index which was reviewed and adjusted to specialist requirements. The stress flow index is provided in Figure 8.1 and a description of the habitat associated with the stress is provided in Table 8.1.

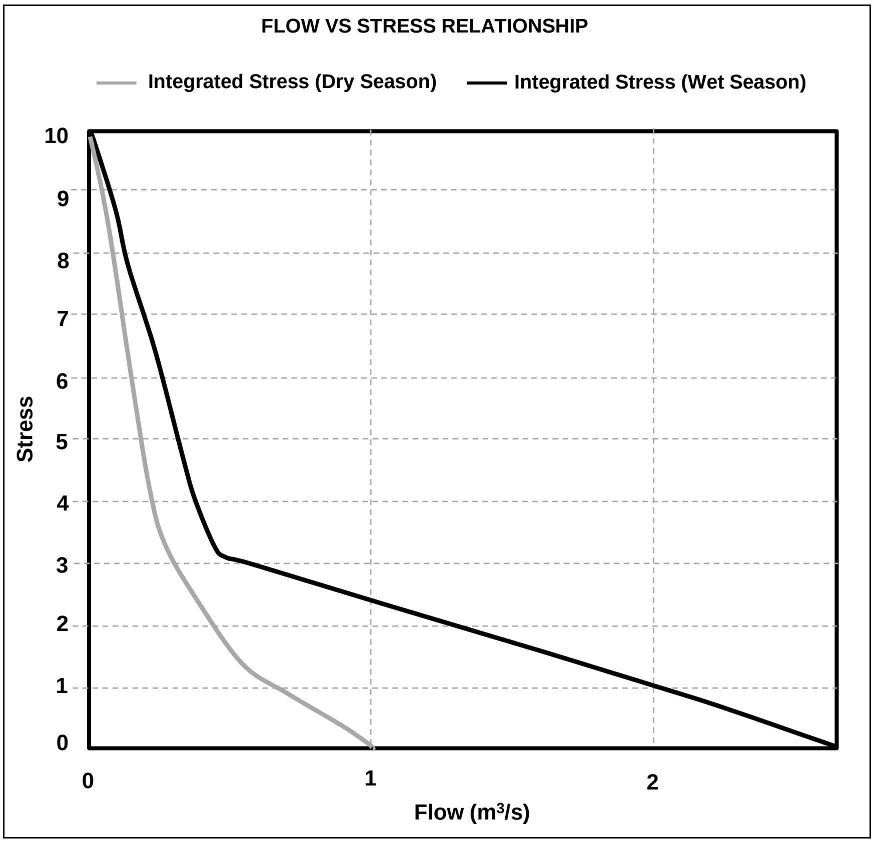

Figure 8.1 Mg_R_EWR1: Stress index

Table 8.1 Mg_R_EWR1: Integrated stress and summarised habitat/biotic responses for the dry and wet season

Stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
2	*0.411*	*Adequate fast habitats to ensure limited stress (as observed during site visit and reflected by available habitat and biota):* ▪ *13% FS.* ▪ *20% FI.* ▪ *10% FD.* ▪ *26% FCS.* ▪ *12%VFCS.*	*1.225*	*Adequate fast habitats to ensure limited stress:* ▪ *8% FS.* ▪ *12% FI.* ▪ *42% FD.* ▪ *20% FCS.* ▪ *30% VFCS.*
5	*0.171*	*Some fast habitats available which is adequate to maintain biota with moderate stress:* ▪ *17% FS.* ▪ *4% FI.* ▪ *3% FD.* ▪ *20% FCS.* ▪ *5% VFCS.*	*0.303*	*Slightly reduced fast habitats resulting in moderate stress on biota:* ▪ *17% FS.* ▪ *15% FI.* ▪ *6% FD.* ▪ *25% FCS.* ▪ *9% VFCS.*

Stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
8	*0.068*	*Very limited fast habitats available, just adequate to maintain biota with serious stress on instream biota:* ▪ *5% FS.* ▪ *2% FI.* ▪ *0% FD.* ▪ *10% FCS.* ▪ *2%VFCS.*	*0.121*	*Largely reduced fast habitats resulting in high stress on biota:* ▪ *13% FS.* ▪ *3% FI.* ▪ *1% FD.* ▪ *15% FCS.* ▪ *3% VFCS.*

8.2 STRESS WEIGHTINGS

The stress weightings are provided in Table 8.2.

Table 8.2 Mg_R_EWR1: Stress weightings

Parameters	Dry stress	Motivation	Wet stress	Motivation
Stress at 0 FS	*9*	*Some rheophilic macroinvertebrate taxa need fast flows to maintain their ecological integrity, driven by habitat and water quality. Fish has a lower requirement for fast habitats during the dry season due to only semi-rheophilic species being present.*	*9*	*Large semi-rheophilic species (L. natalensis) require fast flows during the wet season as spawning habitat. Fast habitats are also required to provide feeding grounds for juvenile eels. Loss of flow will also reduce water quality (especially oxygen) that is required to maintain habitat quality (especially nursery areas for larvae). Loss of fast habitats will also be detrimental to rheophilic macroinvertebrate taxa.*
Parameters	**Weight**	**Motivation**	**Weight**	**Motivation**
FS	*1*	*Good mix of viable habitats in fast flows over stones is favourable to maintain the macroinvertebrate assemblage.*	*2*	*It is more important to maintain deeper habitats (FI and FD) than FS as large semi-rheophilic fish species are present (requirement for deeper fast habitats).*
FI	*1*		*4*	
FD	*1*		*5*	

8.3 INSTREAM BIOTA REQUIREMENTS

The RDRM generates the stress (and flow) requirements for different ECs. Once specialists are satisfied that these results (Figure 8.2) are adequate to maintain the river at the appropriate EC, descriptions are provided for key stress points (Table 8.3)

Table 8.3 Mg_R_EWR1: Stress requirements and habitat and biota description

PES: B	Dry season		Wet season	
Percentile	Flow (m^3/s)	Description	Flow (m^3/s)	Description
95% (drought)	*0.055*	*Biota will be notably stressed but flow should be adequate to allow survival and ensure maintenance of aquatic population in PES:* ▪ *4% FS.* ▪ *2% FI.* ▪ *0% FD.* ▪ *9% FCS.* ▪ *2% VFCS.*	*0.225*	*Although the biota will be stressed, adequate fast habitats (abundance and diversity) will be maintained:* ▪ *17% FS.* ▪ *8% FI.* ▪ *4% FD.* ▪ *22% FCS.* ▪ *6% VFCS.*
70%	*0.107*	*Although thought to be relatively low flow (high stress), it should be adequate to maintain the biota in the PES:* ▪ *10% FS.* ▪ *3% FI.*	*0.325*	*Adequate fast habitats to maintain biota (especially for large semi-rheophilic species (L. natalensis)) in healthy state:* ▪ *15% FS.* ▪ *16% FI.* ▪ *7% FD.*

PES: B	Dry season		Wet season	
Percentile	Flow (m^3/s)	Description	Flow (m^3/s)	Description
		▪ *1% FD.* ▪ *14% FCS.* ▪ *3% VFCS.*		▪ *26% FCS.* ▪ *10% VFCS.*

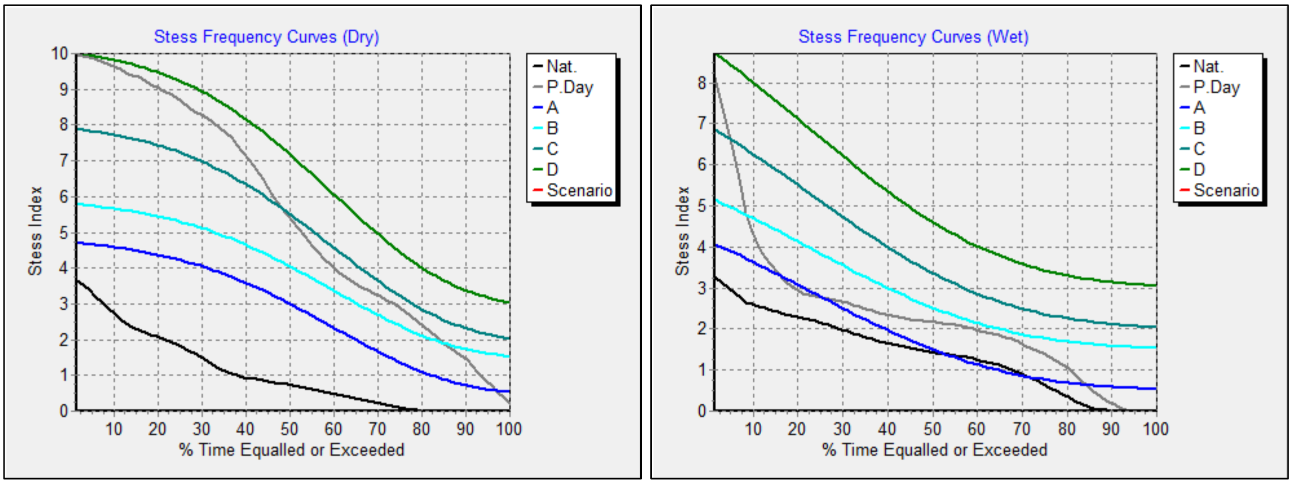

Figure 8.2 Mg_R_EWR1: Stress frequency curves for the dry and wet season

8.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

The above flows were checked by the riparian vegetation specialist to ensure that these requirements were adequate for the marginal and any other flow dependant vegetation to achieve the EC. The vegetation indicators used were Setaria sphacelata and Gomphostigma virgatum which activate at 0.7 m^3/s. The % time that the indicators are activated in each month by the flows specified for the C EC are provided in Table 8.4.

Table 8.4 Mg_R_EWR1: % time that vegetation indicators are activated at a discharge of 0.7 m^3/s

Month	% time that vegetation indicators are activated
Oct	*0*
Nov	*0*
Dec	*10*
Jan	*30*
Feb	*30*
Mar	*30*
Apr	*30*
May	*10*
Jun	*0*
Jul	*0*
Aug	*0*
Sep	*0*

Low flows that were specified will not result in any inundation of marginal zone vegetation (summer or winter) at 40% or 50%. Water stress likely to be evident; high flows are thus important for survival and growth. The confidence is low due to lack of surveyed vegetation.

8.5 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in Table 8.5 and final high flow results are provided in Table 8.6.

Table 8.5 Mg_R_EWR1: Identification of instream functions addressed by the identified floods for riparian vegetation

Flood Class Flood Range (Peak in m³/s)	Riparian vegetation motivation	Fish flood functions						Macroinvertebrate flood functions			
		Migration cues & spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
CLASS I (1 – 2)	*Generally required to inundate marginal and lower zone vegetation.* ▪ *Prevents establishment of terrestrial or some alien species in the marginal zone.* ▪ *Provides recruitment opportunities in the marginal and lower zones.* ▪ *Stimulates growth and reproduction. Prevents encroachment of marginal zone vegetation towards the channel.* ▪ *Specifically at the site these flows activate and inundate Setaria sphacelata and Gomphostima virgatum.*	√	√	√	√	√	√	√	√		√
CLASS II (6 - 10)	*Generally the same function as above. At the site these flows flood sedges and hydrophilic grasses.*	√	√	√	√	√	√	√	√		√
CLASS III (≥ 20)	*Required to inundate lower zone vegetation and activate upper zone vegetation. Similar functions to above in these zones.* ▪ *Maintains heterogeneity in the marginal zone.* ▪ *Activates the shrub and tree layer, which is predominantly alien.*	√	√	√	√	√	√			√	√

The availability of high flows was verified using the observed data at gauge U2H013 (downstream of the EWR site).

Table 8.6 Mg_R_EWR1: The recommended number of high flow events required

Flood Class (Peak in m^3/s)	Flood requirements*	Months	Daily Ave.	Duration (days)
CLASS I (1 – 2)	*6*	*Growing season (spring to summer). It would be valuable for fish to have at least one or two of these in late spring/early summer.*	*1.2*	*2*
CLASS II (6 - 10)	*2*	*Summer*	*6*	*4*
CLASS III (≥ 20)	*1*	*Summer*	*15*	*6*

8.6 EWR RESULTS

The results are provided as an EWR table (Table 8.7) and an EWR rule (Table 8.8). Detailed results are provided in the model generated report for each category in Appendix C.

The low flow EWR rule table is useful for operating the system, whereas the EWR table must be used for operation of high flows. A summary of the results is provided in Table 8.9.

Table 8.7 Mg_R_EWR1: EWR table for Instream PES and REC: C

Month	Low Flows			High Flows (m^3/s)	
	Drought (90%) (m^3/s)	70% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
Oct	*0.053*	*0.206*	*0.330*	*1.2*	*2*
Nov	*0.125*	*0.421*	*0.569*	*1.2*	*2*
Dec	*0.133*	*0.565*	*0.764*	*1.2* *6*	*2* *4*
Jan	*0.186*	*0.657*	*0.908*	*1.2* *15*	*2* *6*
Feb	*0.234*	*0.685*	*0.920*	*1.2* *6*	*2* *4*
Mar	*0.274*	*0.651*	*0.861*	*1.2*	*2*
Apr	*0.262*	*0.485*	*0.662*		
May	*0.212*	*0.250*	*0.322*		
Jun	*0.140*	*0.170*	*0.241*		
Jul	*0.037*	*0.128*	*0.201*		
Aug	*0.019*	*0.109*	*0.176*		
Sep	*0.016*	*0.072*	*0.158*		

Table 8.8 Mg_R_EWR1: Assurance rules (m^3/s) for instream PES and REC: C

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	*0.978*	*0.794*	*0.573*	*0.431*	*0.330*	*0.264*	*0.206*	*0.105*	*0.053*	*0.014*
Nov	*1.715*	*1.384*	*1.054*	*0.752*	*0.569*	*0.512*	*0.421*	*0.305*	*0.125*	*0.088*
Dec	*2.489*	*1.969*	*1.476*	*1.058*	*0.764*	*0.680*	*0.565*	*0.395*	*0.133*	*0.125*
Jan	*2.904*	*2.387*	*1.850*	*1.279*	*0.908*	*0.787*	*0.657*	*0.460*	*0.186*	*0.124*
Feb	*2.856*	*2.363*	*1.843*	*1.288*	*0.920*	*0.821*	*0.685*	*0.488*	*0.234*	*0.131*
Mar	*2.550*	*2.105*	*1.649*	*1.153*	*0.861*	*0.767*	*0.651*	*0.495*	*0.274*	*0.191*
Apr	*1.740*	*1.468*	*1.227*	*0.922*	*0.662*	*0.579*	*0.485*	*0.377*	*0.262*	*0.140*
May	*0.694*	*0.646*	*0.600*	*0.445*	*0.322*	*0.273*	*0.250*	*0.235*	*0.212*	*0.058*

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Jun	*0.513*	*0.441*	*0.359*	*0.301*	*0.241*	*0.194*	*0.170*	*0.166*	*0.140*	*0.019*
Jul	*0.463*	*0.364*	*0.306*	*0.243*	*0.201*	*0.156*	*0.128*	*0.093*	*0.037*	*0.014*
Aug	*0.385*	*0.343*	*0.274*	*0.210*	*0.176*	*0.146*	*0.109*	*0.051*	*0.019*	*0.007*
Sep	*0.375*	*0.307*	*0.239*	*0.191*	*0.158*	*0.129*	*0.072*	*0.039*	*0.016*	*0.000*

Table 8.9 Mg_R_EWR1: Summary of results as a percentage of the nMAR

EWR site	PES & REC	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
Mg_R_EWR1	*Instream: C*	*79.22*	*60.46*	*10.88*	*13.70*	*9.86*	*12.50*	*20.74*	*26.20*

9 ECOCLASSIFICATION: KARKLOOF RIVER (MG_R_EWR3)

9.1 EIS RESULTS

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

- *Critical instream refugia: Critical refuge from uMngeni which is impacted by bottom releases from Midmar Dam at times.*
- *Rare and Endangered riparian species: Crinum macowanii (Declining); Cyathea capensis var. capensis (Declining); Gunnera perpensa (Declining); Hydrostachys polymorpha (Vulnerable); Ilex mitis var. mitis (Declining);*
- *Refugia and critical riparian habitat: Refugia for above rare and endangered riparian species. .*
- *Falls within a private nature reserve.*

9.2 PRESENT ECOLOGICAL STATE

The PES reflects the changes in terms of the EC from reference conditions. The summarised PES information is provided in Table 9.1 and water quality and diatom information is provided in Appendix A and B respectively.

Table 9.1 Mg_R_EWR3: Present Ecological State

IHI Hydrology: PES: C, Confidence: 3
The nMAR is 70.11 MCM and pMAR is 56.5 MCM (80.6% of the nMAR). The baseflow volumes have decreased from natural due to afforestation and irrigation water use. No changes in seasonality were observed for low flows and moderate and large floods have remained relatively stable.
Physico-chemical variables: PES: B, Confidence:3
The upper Karkloof is dominated by commercial forestry with agriculture (irrigation) in the lower section towards the Karkloof Waterfall. Water quality state is Good (B category), with the only impact being some elevated nutrients from upstream irrigation. The confidence is low as no reference condition data were available and the water quality monitoring site is not within the same Level II EcoRegion as the EWR site.
IHI Instream: PES: C, Confidence 2.5 IHI Riparian: PES: B, Confidence 4
The instream IHI is mainly impacted on by algal and benthic growth. The banks have been modified with off channel dams, extensive crossings and dams. *The impact on riparian integrity is generally low. Longitudinal connectivity is impacted by weirs and dams and alien vegetation was observed in the marginal and non-marginal zone.*
Riparian vegetation: PES: B, Confidence: 3
Marginal Zone: Narrow, mainly grasses especially Setaria sphacelata. *Lower Zone: Mixed grasses, forbs and shrubs with Syzygium cordatum.* *Upper Zone: Narrow, mixed but dominated by woody species.* *MCB: Steep, dominated by woody species.* *Main impacts at the site include the presence of alien plant species such as Ageratum conyzoides, Argemone mexicana, Chromolaena odorata, Colocasia esculenta, Acacia mearnsii and Lantana camara. Also, nutrients may be elevated since there was a high prevalence of filamentous algae. There is also some physical clearing of vegetation in the upper zone.*
Fish: PES: B/C, Confidence: 2
Based on the available fish distribution data and expected habitat composition, eleven indigenous fish species are expected under reference conditions (A. marmorata, A. mossambica, A. natalensis, B. anoplus, B. gurneyi, L. natalensis, B. viviparous, C. gariepinus, O. mossambicus, Tilapia rendalli and T. sparrmanii). The presence of five of the expected species was confirmed during a survey conducted in August 2013. Based on all available information it is estimated that all the fish species expected under natural conditions are still present in this river reach under present conditions, most in similar FROC as expected under reference conditions. The most notable impact is associated with the presence of migration barriers (especially large downstream dams) resulting in decreased migration success of especially the catadromous eels (A. marmorata, and A. mossambica), as well as a minor impact on potadromous species (especially L. natalensis).

Macroinvertebrates: PES: B, Confidence: 2
A total of 22 SASS5 taxa were recorded during the field survey in June 2012 compared to 54 expected under natural conditions. Under these conditions, the SASS score was 163 with an ASPT of 7.4, which reflects a reference condition. The suitability of the river for taxa with a preference for very high flows was moderate (60% of expected taxa), and for high flows was also moderate (56% of expected taxa). These conditions can be attributed to upstream dams and weirs in the system. Taxa expected but not recorded included Oligoneuridae, Prosopistomatidae, Polymitarcyidae, Pyralidae and Philopotamidae. The suitability of the river for taxa with a preference for SIC instream habitats was high (63% of expected taxa), but riverine vegetation was low (13% of expected taxa). The lower vegetation integrity can be ascribed to vegetation clearing and alien invaders. Taxa expected in the vegetation biotope but not recorded included Dytiscidae, Lestidae, Platycnemidae, Hydroptilidae, Nepidae, Chlorolestidae, and Lymnaeidae. The suitability of the river for taxa with a high requirement for unmodified physico-chemical conditions was moderate (50% of expected taxa), and moderate conditions was low (47% of expected taxa). Adverse conditions that might influence the water quality could be: sediment transport, increased nutrients that results in the presence of algae. Taxa expected but not recorded included Helodidae, Philopotamidae, Corduliidae, Chlorocyphidae and Gerridae.

The PES EcoStatus is a B EC and the EcoStatus models are provided electronically. Flow related impacts are mainly related to reduced baseflows due to upstream irrigation activities. The main non-flow-related issues are localised impacts of roads, small farm dams, crossings and water quality problems from upstream irrigation.

9.3 RECOMMENDED ECOLOGICAL CATEGORY

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability there-of. Although the EIS was HIGH, the instream components were all in a B EC and therefore no improvement was required. The REC was therefore set to maintain the PES. The final EcoClassification results are summarised in Table 9.2.

Table 9.2 Mg_R_EWR3: Summary of EcoClassification results

Component	PES & REC
IHI Hydrology	B
Physico chemical	B
Fish	B/C
Invertebrates	B
Instream	B
Riparian vegetation	B
EcoStatus	B
Instream IHI	C
Riparian IHI	B
EIS	HIGH

10 EWR REQUIREMENTS: KARKLOOF RIVER (MG_R_EWR3)

10.1 FLOW VS STRESS RELATIONSHIP

The RDRM generated a stress flow index which was reviewed and adjusted to specialist requirements. The stress flow index is provided in Figure 10.1 and a description of the habitat associated with the stress is provided in Table 10.1.

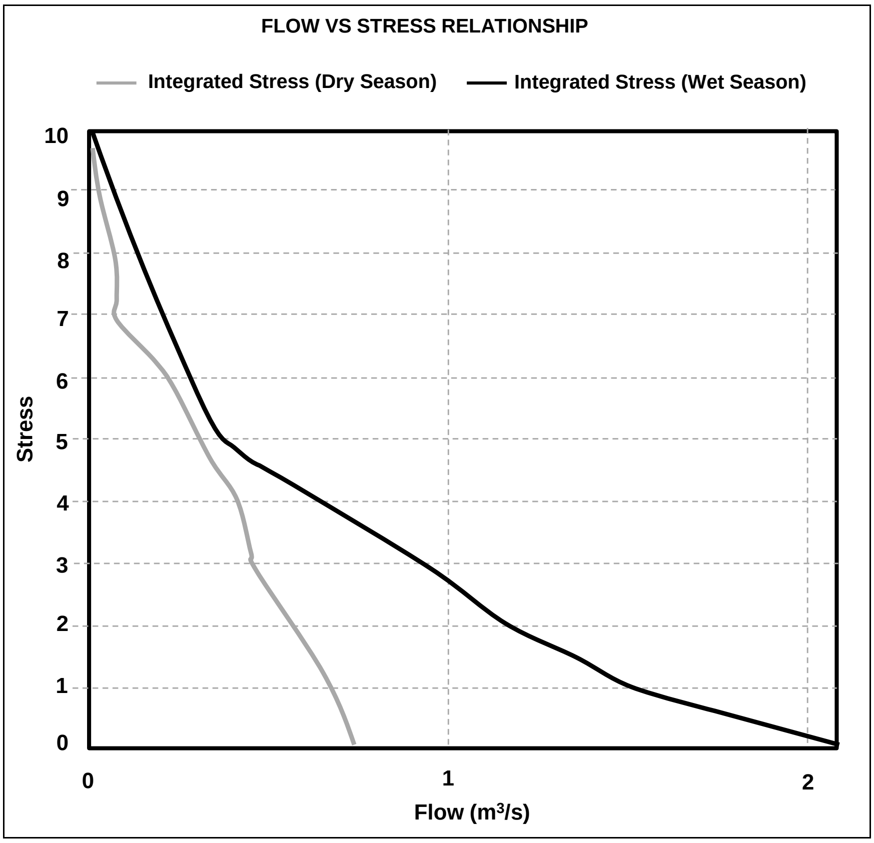

Figure 10.1 Mg_R_EWR3: Stress index

Table 10.1 Mg_R_EWR3: Integrated stress and summarised habitat/biotic responses for the dry and wet season

Stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
2	*0.555*	*Adequate fast habitats ensure limited stress:* ▪ *13% FS.* ▪ *3% FI.* ▪ *10% FD.* ▪ *18% FCS.* ▪ *5% VFCS.*	*1.174*	*Adequate fast habitats during wet season to ensure limited stress (as observed during site visit and reflected by available habitat and biota):* *7% FS.* *17% FI.* *19% FD.* *24% FCS.* *10% VFCS.*
5	*0.304*	*Some fast habitats available, adequate to maintain biota with moderate stress:* ▪ *5% FS.* ▪ *6% FI.* ▪ *2% FD.* ▪ *14% FCS.* ▪ *3% VFCS.*	*0.342*	*Slightly reduced fast habitats resulting in moderate stress on biota:* ▪ *7% FS.* ▪ *6% FI.* ▪ *3% FD.* ▪ *14% FCS.*

Stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
				▪ 4% VFCS.
8	*0.056*	*Very limited fast habitats available, just adequate to maintain biota with serious stress on instream biota:* ▪ *6% FS.* ▪ *1% FI.* ▪ *0% FD.* ▪ *6% FCS.* ▪ *0 % VFCS.*	*0.137*	*Largely reduced fast habitats resulting in high stress on biota:* ▪ *5% FS.* ▪ *3% FI.* ▪ *0% FD.* ▪ *9% FCS.* ▪ *1% VFCS.*

10.2 STRESS WEIGHTINGS

The stress weightings are provided in Table 10.2.

Table 10.2 Mg_R_EWR3: Stress weightings

Parameters	Dry stress	Motivation	Wet stress	Motivation
Stress at zero FS	*9*	*During dry season some rheophilic macroinvertebrate taxa and small rheophilic fish species need fast flows to maintain their ecological integrity, driven by habitat and water quality.*	*9*	*Large semi-rheophilic species (L. natalensis) require fast flows during the wet season for spawning habitat. Fast habitats are also important for small rheophilic species (A. natalensis). Loss of flow will also reduce water quality (especially oxygen) that is required to maintain habitat quality (especially nursery areas for larvae). Loss of fast habitats will also be detrimental to rheophilic macroinvertebrate taxa.*
Parameters	**Weight**	**Motivation**	**Weight**	**Motivation**
FS	*1*	*A good mix of viable habitats in fast flows over stones is favourable to maintain the macoinvertebrate assemblage during the dry season. The high importance of FD habitats is attributed to the importance to meet the requirement of the high rheophilic macroinvertebrate and fish guild and maintain high habitat diversity in the dry season.*	*3*	*It is more important to maintain deeper habitats (FI and FD) than FS as large semi-rheophilic fish species are present (requirement for deeper fast habitats). The presence of small rheophilic species however necessitates the maintenance of FS and FI.*
FI	*4*		*4*	
FD	*10*		*5*	

10.3 INSTREAM BIOTA REQUIREMENTS

The RDRM generates the stress (and flow) requirements for different ECs. Once specialists are satisfied that these results Figure 10.2) are adequate to maintain the river at the appropriate EC, descriptions are provided for key stress points (Table 10.3)

Table 10.3 Mg_R_EWR3: Stress requirements and habitat and biota description

PES: B	Dry season		Wet season	
Percentile	Flow (m^3/s)	Description	Flow (m^3/s)	Description
95% (drought)	*0.015*	*Biota will be notably stressed but flow should be adequate to allow survival and ensure maintenance in PES:* ▪ *4% FS.* ▪ *5% FI.* ▪ *0% FD.* ▪ *11% FCS.* ▪ *2% VFCS.*	*0.32*	*Although the biota will be somewhat stressed, adequate fast habitats (abundance and diversity) will be maintained:* ▪ *7% FS.* ▪ *6% FI.* ▪ *3% FD.* ▪ *14% FCS.* ▪ *4% VFCS.*

PES: B	Dry season		Wet season	
Percentile	**Flow (m^3/s)**	**Description**	**Flow (m^3/s)**	**Description**
70%	*0.25*	*Although thought to be relatively low (high stress), it should be adequate to maintain the biota in the PES:* ▪ *5% FS.* ▪ *3% FI.* ▪ *0% FD.* ▪ *9% FCS.* ▪ *1% VFCS.*	*0.61*	*Adequate fast habitats to maintain biota (especially for small rheophilic (A. natalensis) and large semi-rheophilic species (L. natalensis) in healthy state:* ▪ *13% FS.* ▪ *9% FI.* ▪ *12% FD.* ▪ *21% FCS.* ▪ *6% VFCS.*

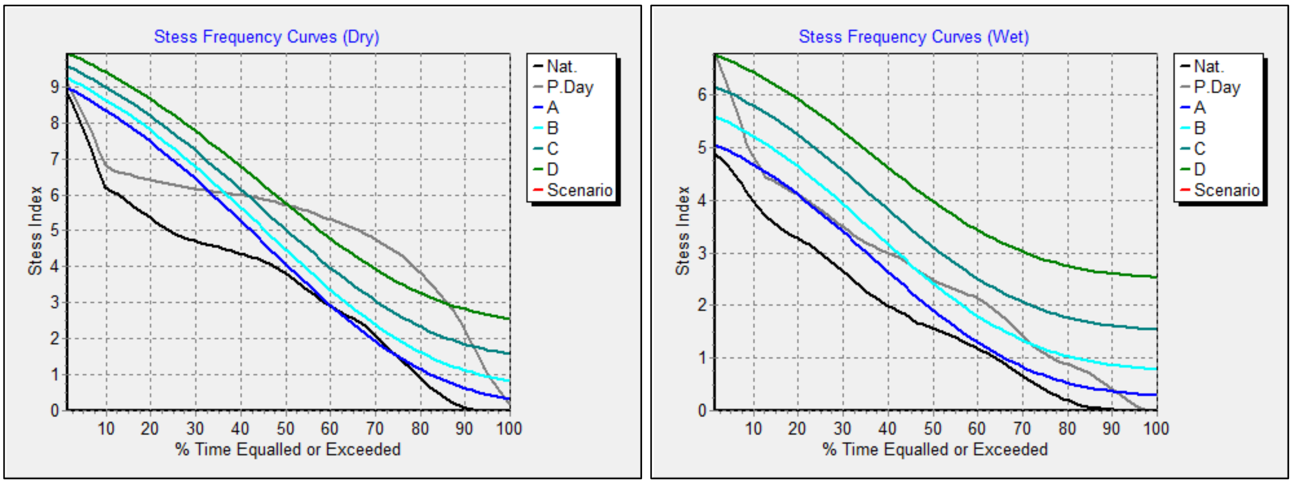

Figure 10.2 Mg_R_EWR3: Stress frequency curves for the dry and wet season

10.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

The above flows were checked by the riparian vegetation specialist to ensure that these requirements were adequate for the marginal and any other flow dependant vegetation to achieve the EC. At this site the vegetation indicators used were Setaria sphacelata and Gomphostigma virgatum which activate at 0.89 m^3/s. The % time that the indicators are activated in each month by the flows specified for the C EC are provided in Table 10.4.

Table 10.4 Mg_R_EWR3: % time that vegetation indicators are activated at a discharge of 0.89 m^3/s

Month	% time that vegetation indicators are activated
Oct	*0*
Nov	*0*
Dec	*20*
Jan	*40*
Feb	*50*
Mar	*60*
Apr	*50*
May	*50*
Jun	*20*
Jul	*0*
Aug	*0*
Sep	*0*

Low flows that were specified will result in some inundation of marginal zone vegetation in March and April (50%), and some wetting in February and May. Water stress is likely to be evident in the dry season months; high flows will be important for longer-term survival and growth.

10.5 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in Table 10.5 and final high flow results are provided in Table 10.6.

Table 10.5 Mg_R_EWR3: Identification of instream functions addressed by the identified floods for riparian vegetation

Flood Class Flood Range (Peak in m^3/s)	Riparian vegetation motivation	Fish flood functions						Macroinvertebrate flood functions			
		Migration cues & spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
CLASS I (2 – 4)	*Inundates marginal and lower zone vegetation.* ▪ *Prevents establishment of terrestrial or some alien species in the marginal zone.* ▪ *Provides recruitment opportunities in the marginal and lower zones.* ▪ *Stimulates growth and reproduction.* ▪ *Prevents encroachment of marginal zone vegetation towards the channel.* ▪ *Specifically at the site these flows inundate hydrophilic grasses (Setaria sphacelata) sedges (C. dives) and Ludwigia octovalvis.*	√	√	√	√	√	√	√	√		√
CLASS II (5 – 7.5)	*Generally the same function as above. At the site these flows activate obligate riparian trees such as Syzygium cordatum and Ficus sur.*	√	√	√	√	√	√	√	√		√
CLASS III (≥10)	*Required to inundate lower zone vegetation and activate upper zone vegetation. Similar functions to above in these zones.* ▪ *Maintains heterogeneity in the marginal and lower zones.* ▪ *Activates the shrub and tree layer, which is predominantly terrestrial.*	√	√	√	√	√	√			√	√

The availability of high flows was verified using the observed data at gauge U2H006 (upstream of the EWR site).

Table 10.6 Mg_R_EWR3: The recommended number of high flow events required

Flood Class (Peak in m^3/s)	Flood requirements*	Months	Daily Ave.	Duration (days)
CLASS I (2 – 4)	*6*	*Growing season (spring to summer).*	*2.5*	*3*
CLASS II (5 – 7.5)	*3*	*Summer*	*5.5*	*4*
CLASS III (≥10)	*1*	*Late summer (Feb - Mar).*	*9*	*6*

10.6 EWR RESULTS

The results are provided as an EWR table (Table 10.7) and an EWR rule (Table 10.8). Detailed results are provided in the model generated report for each category in Appendix C.

The low flow EWR rule table is useful for operating the system, whereas the EWR table must be used for operation of high flows. A summary of the results is provided in Table 10.9.

Table 10.7 Mg_R_EWR3: EWR table for PES and REC: B

Month	Low Flows			High Flows (m^3/s)	
	Drought (90%) (m^3/s)	70% (m^3/s)	50% (m^3/s)	Daily average (m^3/s)	Duration (days)
Oct	*0.043*	*0.224*	*0.358*	*2.5*	*3*
Nov	*0.076*	*0.416*	*0.662*	*2.5*	*3*
Dec	*0.098*	*0.617*	*1.050*	*2.5*	*3*
Jan	*0.117*	*0.788*	*1.384*	*2.5* *5.5*	*3* *4*
Feb	*0.206*	*1.009*	*1.579*	*2.5* *5.5* *9*	*3* *4* *6*
Mar	*0.336*	*1.061*	*1.569*	*2.5* *5.5*	*3* *4*
Apr	*0.253*	*0.805*	*1.277*		
May	*0.194*	*0.590*	*0.952*		
Jun	*0.125*	*0.320*	*0.606*		
Jul	*0.057*	*0.223*	*0.383*		
Aug	*0.054*	*0.161*	*0.304*		
Sep	*0.032*	*0.129*	*0.287*		

Table 10.8 Mg_R_EWR3: Assurance rules (m^3/s) for PES and REC: B

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	*1.236*	*0.703*	*0.454*	*0.396*	*0.358*	*0.313*	*0.224*	*0.115*	*0.043*	*0.018*
Nov	*2.180*	*1.480*	*1.027*	*0.856*	*0.662*	*0.580*	*0.416*	*0.228*	*0.076*	*0.073*
Dec	*3.287*	*2.590*	*1.916*	*1.369*	*1.050*	*0.870*	*0.617*	*0.341*	*0.098*	*0.095*
Jan	*4.122*	*3.161*	*2.400*	*1.819*	*1.384*	*1.130*	*0.788*	*0.441*	*0.117*	*0.070*
Feb	*4.390*	*3.410*	*2.582*	*2.020*	*1.579*	*1.315*	*1.009*	*0.645*	*0.206*	*0.163*
Mar	*3.670*	*3.027*	*2.462*	*1.950*	*1.569*	*1.341*	*1.061*	*0.697*	*0.336*	*0.295*
Apr	*2.510*	*2.172*	*1.829*	*1.555*	*1.277*	*1.053*	*0.805*	*0.532*	*0.253*	*0.181*
May	*1.579*	*1.446*	*1.252*	*1.102*	*0.952*	*0.790*	*0.590*	*0.331*	*0.194*	*0.157*
Jun	*1.047*	*0.976*	*0.819*	*0.706*	*0.606*	*0.522*	*0.320*	*0.191*	*0.125*	*0.112*
Jul	*0.798*	*0.679*	*0.533*	*0.463*	*0.383*	*0.338*	*0.223*	*0.105*	*0.057*	*0.000*

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Aug	*0.716*	*0.526*	*0.418*	*0.350*	*0.304*	*0.284*	*0.161*	*0.073*	*0.054*	*0.020*
Sep	*0.656*	*0.535*	*0.421*	*0.356*	*0.287*	*0.245*	*0.129*	*0.061*	*0.032*	*0.000*

Table 10.9 Mg_R_EWR3: Summary of results as a percentage of the natural nMAR

Long term mean									
EWR site	PES & REC	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
Mg_R_EWR3	*B*	*70.11*	*56.50*	*19.11*	*27.30*	*11.38*	*16.20*	*30.49*	*43.50*

11 ECOCLASSIFICATION: uMNSUNDUZE RIVER (MG_R_EWR4)

11.1 EIS RESULTS

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

- *Diversity of riparian habitat types and features.*
- *Rare and Endangered riparian species: Crinum bulbispermum (Declining).*

11.2 PRESENT ECOLOGICAL STATE

The PES reflects the changes in terms of the EC from reference conditions. The summarised PES information is provided in Table 11.1 and water quality and diatom information is provided in Appendix A and B respectively.

Table 11.1 Mg_R_EWR4: Present Ecological State

IHI Hydrology: PES: E/F, Confidence: 3
The baseflow volumes have decreased from natural due to afforestation and irrigation water use. No changes in seasonality were observed for low flows and moderate and large floods have remained relatively stable.
Physico-chemical variables: PES: E/F, Confidence:3.5
The uMnsunduze River catchment upstream of Pietermarizburg has moderate to serious erosion problems, especially in the Henley Dam catchment. Serious faecal (sewer reticulation and inadequate on-site latrine problems) and general urban pollution arises from Pietermaritzburg, with potentially very serious industrial pollution and significant nutrient enrichment. The water quality in the uMnsunduze downstream of Henley Dam is seriously affected by sewer infrastructure problems, including ingress of rainwater into the sewer system which results in surcharges overloading Darville WWTW. Pit latrines are also extensively used in the area. The Darvill WWTW is the single most important contributor of nutrients to the downstream system, with poorly managed subsistence agriculture, overgrazing and poor sanitation systems downstream. The water quality of the middle and lower uMnsunduze is very poor, with a high faecal coliform content and nutrient enrichment, resulting in significant risks of health effect if the water is used for drinking and contact recreation, e.g. the annual Dusi canoe marathon. The nutrient concentrations in the lower uMnsunduze River are also very high and contribute significantly to the eutrophication processes of the lower uMngeni River. The overall confidence for the assessment is considered to be Moderate to high. The present state category for water quality is an E/F category, primarily because the threshold for oxygen (i.e. a D category, or rating of >3, i.e. oxygen levels of 4 - 6 mg/l) was exceeded. Both DWA and Umgeni Water data were available for this assessment, although data counts for metals were low.
IHI Instream: PES: E/F, Confidence 2.5 IHI Riparian: PES: D/E, Confidence 4.2
The instream IHI is severely impacted by a modified flow regime and deteriorated water quality due to anthropogenic activities. Increased baseflows exceed thresholds and floods have increased. Deteriorated water quality has led to increased nutrient loading within the system and oxygen levels exceed thresholds. Algal and benthic growth is high along with sedimentation and overall bed and bank modification impacts are present. *The impact on riparian integrity is also severe. Erosion, altered hydrology and deteriorated water quality have influenced bank structure. Alien vegetation has impacted connectivity due to structure modification in the marginal and non-marginal zone.*
Riparian vegetation: PES: D/E, Confidence: 3.1
Marginal and Lower Zones: Marginal and lower zone almost absent, narrow and constrained between high flow and eroded, steep banks. A mix of non-woody vegetation, many of which are alien. *Upper Zone: Steep, with terraces in places. Mostly woody aliens, up to 30 - 40% and highly disturbed, including physical clearing.* *MCB: Large scale clearing and disturbance with a high density of aliens, both woody and non-woody.* *Main impacts at the site are elevated flows (which have drowned out the marginal and lower zones), elevated nutrients as seen from vigorous watercress growth, intense invasion by alien plant species (watercress, bramble, mulberry, wattle, blue gum, and Lantana camara), extensive clearing of vegetation and physical disturbance of the banks.*
Fish: PES: E, Confidence: 2
Based on the available fish distribution data and expected habitat composition, thirteen indigenous fish species are expected under reference conditions (A. aeneofuscus, A. bengalensis, A. mossambica, A. natalensis, B. gurneyi, L natalensis, Barbus pallidus, B. viviparous, C. gariepinus, O. mossambicus, Pseudocrenilabrus philander, T. rendalli and T. sparrmanii). The presence of only one of the expected species (L. natalensis) was confirmed during a survey conducted in August 2013. Based on all available information it is estimated that the FROC of all species have been reduced significantly and that A. aeneofuscus, A. natalensis and B. gurneyi may have disappeared from this river reach

as a result of the deterioration. Serious deterioration in water quality contributed to potential decreased FROC and disappearance of species with intolerance to physico-chemical alteration (such as B. gurneyi, A. natalensis, L. natalensis, B. pallidus). The increase in base flows have altered habitat composition and impacted on all species as a result of the change in habitat composition. Increased sedimentation (erosion, urbanization, overgrazing), excessive algal growth (nutrient enrichment) and extensive solid waste disposal reduced the FROC of species with a preference for substrate as cover (A. natalensis and L. natalensis). Extensive alteration in the condition and availability of the marginal zone (overhanging vegetation) due to high flows and bank erosion decreased the FROC of species with a preference for this cover type (A. aeneofuscus, T. sparrmanii, B. gurneyi, B. viviparous, P. philander, and T. rendalli). The serious reduction and alteration in food sources (especially macroinvertebrates) may also have contributed slightly to the decreased FROC of all species.
Macroinvertebrates: PES: E, Confidence: 3
A total of 9 SASS5 taxa were recorded during the field survey in June 2012 compared to 59 expected under natural conditions. Under these conditions, the SASS score was 47 with an ASPT of 5.2, which reflects a "Fair" condition, bordering on "Poor". The suitability of the river for taxa with a preference for very high flows was zero (0% of expected taxa), and for high flows was low (33% of expected taxa). These conditions can be attributed to upstream weirs in the system, abstraction, regulation and return flows (unnatural flow regimes). Seventeen taxa were expected for the fast flow preferences, but only three taxa (18% of expected taxa) were recorded. The lower habitat scores can be ascribed to flow changes, water level fluxes, alien vegetation, drowning out of marginal vegetation and bank disturbances; however the water quality is exceptionally poor in all the habitats, nullifying all good habitats. The suitability of the river for taxa with a preference for both the SIC instream habitats and the riverine vegetation was very low (11% and 19% of expected taxa respectively). The suitability of the river for taxa with a high requirement for unmodified physico-chemical conditions was very low (14% of expected taxa), and moderate conditions was also very low (5% of expected taxa). Adverse conditions that might influence the water quality could be: the impacts emanating from the city of Pietermaritzburg, sewage works, toxicity, high nutrient problems, low oxygen content, elevated salinity and organics (excessive algal growth).

The PES EcoStatus is a D/E EC and the EcoStatus models are provided electronically. Although increased floods and baseflows that exceed thresholds are important flow related impacts in the reach, water quality is the major non-flow related impact which drives the deteriorated ecological condition of the river reach and is exacerbated by poor sewer infrastructure and industrial pollution leading to low oxygenation rates, high faecal coliform counts and excessive nutrient loading within the system. Intense alien vegetation infestation also impacts the reach severely.

11.3 RECOMMENDED ECOLOGICAL CATEGORY

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability there-of. As the EIS was LOW no improvement was required. All components were in an unsustainable EC (lower than a D EC), and therefore the REC had to be set at a D. As the water quality issues are the primary problem, these need to be addressed at source first prior to any attention being given to addressing the flow issues. Therefore, no flow requirement was set for this EWR site. The final EcoClassification results are summarised in Table 11.2.

Table 11.2 Mg_R_EWR4: Summary of EcoClassification results

Component	PES	REC
IHI Hydrology	E	N/A
Physico chemical	E/F	D
Fish	E	D
Invertebrates	E	D
Instream	E	D
Riparian vegetation	D/E	D
EcoStatus	D/E	D
Instream IHI	E/F	D
Riparian IHI	D/E	D
EIS	LOW	

12 CONCLUSIONS AND RECOMMENDATIONS

12.1 ECOCLASSIFICATION

The EcoClassification results are summarised below in Table 12.1.

Table 12.1 EcoClassification Results summary

MT_R_EWR1: MTAMVUNA RIVER

EIS: MODERATE
Highest scoring metrics were migration route for eel species in the system. Rare and endangered riparian species occur and therefore this reach is important in terms of refugia and critical riparian habitat.

PES: C
- *General loss of connectivity and bank modification due to overgrazing, trampling, alien invasive vegetation and wood removal in the riparian zones.*
- *Increased nutrients due to deteriorated water quality.*

REC: C
As the EIS was MODERATE no improvement was required. The REC was therefore set to maintain the PES. Due to non-flow related impacts on riparian vegetation, the EWR were set for the instream EC of a B.

Component	PES & REC
IHI Hydrology	A/B
Physico chemical	A/B
Fish	B/C
Invertebrates	B
Instream	B
Riparian vegetation	C/D
EcoStatus	C
Instream IHI	B/C
Riparian IHI	C
EIS	MODERATE

LO_R_EWR1: LOVU RIVER

EIS: MODERATE
Highest scoring metrics were diversity of habitat types and features, the reach is important for the migration of eel species and macroinvertebrates in the system and rare and endangered riparian species are present.

PES: B/C
- *Reduced base flows due to dams and general landuse in the upper catchment.*
- *Deteriorated water quality and increased sedimentation due to livestock farming, WWTW, sand mining and sugarcane farming.*
- *Alien invasive vegetation and wood removal in the riparian zones.*

REC: B/C
EIS was MODERATE and the REC was therefore to maintain the PES.

Component	PES & REC
IHI Hydrology	B
Physico chemical	B/C
Fish	B/C
Invertebrates	B/C
Instream	B/C
Riparian vegetation	B/C
EcoStatus	B/C
Instream IHI	B/C
Riparian IHI	B/C
EIS	MODERATE

MG_R_EWR1: MGENI RIVER

EIS: LOW
Highest scoring metrics were diversity of habitat types and features as well as the presence of rare and endangered riparian species.

PES: C/D

- *The presence of aggressive alien fish species and exotic vegetation species.*
- *Some decrease in base flows due to abstractions for agriculture.*

REC: C/D
As the EIS was LOW no improvement was required. The C/D EcoStatus PES mainly due to non-flow related impacts and not representative of flow related problems in the reach. It was decided to exclude alien fish species from the assessment resulting in a PES of a C EC for fish and an instream PES of a C EC for which flow requirements were set.

Component	PES & REC
IHI Hydrology	B
Physico chemical	B
Fish	D (C)
Invertebrates	C
Instream	C/D (C)
Riparian vegetation	C/D
EcoStatus	C/D
Instream IHI	C
Riparian IHI	C
EIS	LOW

MG_R_EWR3: KARKLOOF RIVER

EIS: HIGH
The reach falls within a private nature reserve and serves as critical instream refuge from uMngeni which is impacted by bottom releases from Midmar Dam at times. Rare and endangered riparian species occur and therefore this reach is important in terms of refugia and critical riparian habitat.

PES: B

- *Reduced baseflows due to upstream irrigation activities.*
- *Localised impacts of roads, small farm dams, crossings and water quality problems from upstream irrigation.*

REC: B
Although the EIS was HIGH, the instream components were all in a B EC and therefore no improvement was required. The REC was therefore set to maintain the PES.

Component	PES & REC
IHI Hydrology	B
Physico chemical	B
Fish	B/C
Invertebrates	B
Instream	B
Riparian vegetation	B
EcoStatus	B
Instream IHI	C
Riparian IHI	B
EIS	HIGH

MG_R_EWR4: MSUNDUZE RIVER	
EIS: LOW *Highest scoring metrics were diversity of habitat types and features as well as the presence of rare and endangered riparian species* **PES: D/E** ▪ *Increased floods and baseflows that exceed thresholds are important flow related impacts in the reach.* ▪ *Water quality is the major impact which drives the deteriorated ecological condition and is exacerbated by poor sewer infrastructure and industrial pollution leading to low oxygenation rates, high faecal coliform counts and excessive nutrient loading within the system.* ▪ *Intense alien vegetation infestation also impacts the reach severely.* **REC: D** *As the EIS was LOW no improvement was required. All components were in an unsustainable EC (lower than a D EC), and therefore the REC had to be set at a D. As the water quality issues are the primary problem, these need to be addressed at source first prior to any attention being given to addressing the flow issues. Therefore, no flow requirement was set for this EWR site.*	

Component	PES	REC
IHI Hydrology	E/F	N/A
Physico chemical	E/F	D
Fish	E	D
Invertebrates	E	D
Instream	E	D
Riparian vegetation	D/E	D
EcoStatus	D/E	D
Instream IHI	E/F	D
Riparian IHI	D/E	D
EIS	LOW	LOW

The confidence in the EcoClassification process is provided below (Table 12.2) and was based on data and information availability and EcoClassification where:

- *Data and information availability: Evaluation based on the adequacy of any available data for interpretation of the EC and AEC.*
- *EcoClassification: Evaluation based on the confidence in the accuracy of the Present Ecological State.*

The confidence score is based on a scale of 0 – 5 and colour coded where:

0 – 1.9: Low *2 – 3.4: Moderate* *3.5 – 5: High*

These confidence ratings are applicable to all scoring provided in this chapter.

Table 12.2 Confidence in EcoClassification

EFR site	Data and information availability								EcoClassification							
	Hydrology	Water Quality	IHI	Fish	Inverts	Vegetation	Average	Median	Hydrology	Water Quality	IHI	Fish	Inverts	Vegetation	Average	Median
Mt_R_EWR1	1.5	3.0	3.0	2.0	2.0	3.0	**2.4**	**2.5**	1.0	3.0	3.4	2.0	2.0	2.6	**2.5**	**2.8**
Lo_R_EWR1	1.5	3.0	3.0	2.0	2.0	3.0	**2.4**	**2.5**	1.0	3.0	3.0	2.0	2.0	3.0	**2.3**	**2.5**
Mg_R_EWR1	4.0	3.0	3.0	2.0	2.0	3.0	**2.8**	**3.0**	3.0	3.5	3.4	2.0	2.0	2.9	**2.8**	**3.0**
Mg_R_EWR3	4.0	1.0	3.0	2.0	2.0	3.0	**2.5**	**2.5**	3.0	1.0	3.3	2.0	2.0	3.0	**2.4**	**2.5**
Mg_R_EWR4	4.0	3.0	3.0	2.0	2.0	3.0	**2.8**	**3.0**	3.0	3.5	3.4	2.0	2.0	3.1	**3.0**	**3.1**

The confidence in data availability and EcoClassification was mostly Moderate at all the EWR sites. The confidence is higher at Mg_R_EWR1 and Mg_R_EWR4 due to better driver information.

12.2 ECOLOGICAL WATER REQUIREMENTS

The final flow requirements are expressed as a percentage of the nMAR in Table 12.3.

Table 12.3 Summary of results as a percentage of the nMAR

				Long term mean					
EWR site	PES and REC	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%nMAR)	High flows (MCM)	High flows (%nMAR)	Total flows (MCM)	TOTAL (%nMAR)
Mt_R_EWR1	*Instream: B*	*233.15*	*200.69*	*60.99*	*26.20*	*35.08*	*15.00*	*96.07*	*41.20*
Lo_R_EWR1	*B/C*	*87.76*	*73.42*	*20.04*	*22.80*	*13.19*	*15.10*	*33.23*	*37.90*
Mg_R_EWR1	*Instream: C*	*79.22*	*60.46*	*10.88*	*13.70*	*9.86*	*12.50*	*20.74*	*26.20*
Mg_R_EWR3	*B*	*70.11*	*56.50*	*19.11*	*27.30*	*11.38*	*16.20*	*30.49*	*43.50*

1 Present Mean Annual Runoff

The hydrology confidence is summarised in Table 12.4. The hydraulics confidence is summarised in Table 12.5. The hydraulics confidence when applying the RERM represents the overall confidence in the EWR as it is the most important variable.

Table 12.4 Confidence in hydrology

EWR site	Natural hydrology	Present hydrology	Comment	Confidence: Median	Confidence: Average
Mt_R_EWR1	*2*	*1*	*The lack of a gauge results in a lower confidence.*	*1.5*	*1.5*
Lo_R_EWR1	*2*	*1*	*The lack of a gauge results in a lower confidence.*	*1.5*	*1.5*
Mg_R_EWR1	*4*	*3*	*U2H013 (downstream of EWR site) with 52 years (1960 to 2013) of data.*	*4.0*	*4.0*
Mg_R_EWR3	*4*	*3*	*U2H006 (upstream of EWR site) with 58 years (1954 to 2013) of data.*	*4.0*	*4.0*

Table 12.5 Hydraulic confidence

EWR site	Hydraulics	Comment
Mt_R_EWR1	*3*	*Reasonable simple site with two calibrations instead of the normal one calibration associated with a Rapid.*
Lo_R_EWR1	*3*	*Reasonable simple site with two calibrations instead of the normal one calibration associated with a Rapid.*
Mg_R_EWR1	*1*	*Hydraulic modelling was undertaken for a previous study. No photos were available and the benchmark could not be found. Additional calibration therefore not possible. Cross-section not done to the necessary detail.*
Mg_R_EWR3	*2*	*Complex site with only one calibration. Expected confidence for Rapid hydraulics.*

12.3 RECOMMENDATIONS

The confidence in the EcoClassification is generally moderate which is acceptable for a Rapid assessment. Furthermore, no further work on the EcoClassification is required as it will not influence the EWR determination. However, monitoring is essential to ensure that the ecological objectives in terms of the REC are achieved.

The hydraulics and resulting low confidence at the Mg_R_EWR1 site would require additional hydraulic work (resurvey, photographs, EWR assessment) if any future developments or changes in operation are planned that could require a higher confidence EWR.

The low to moderate confidence of the Mg_R_EWR3 (Karkloof River) can be improved by additional hydraulic calibrations and revision of the EWR. Again this would only be required if any future developments or changes in operation are planned that could require a higher confidence EWR.

13 REFERENCES

Brown, C, and King, J. 2001. Environmental flow assessment for rivers. A summary of the DRIFT process. Southern Waters information Report No 01/00.

Department of Water Affairs and Forestry (DWAF). (1999). Resource Directed Measures for Protection of Water Resources. Volume 3: River Ecosystems Version 1.0, Pretoria.

Department of Water Affairs and Forestry (DWAF), South Africa. 2004. Internal Strategic Perspective: Umvoti to Mzimkulu Water Management Area: Prepared by Tlou & Matji (Pty) Ltd, WRP (Pty) Ltd, and DMM cc on behalf of the Directorate: National Water Resource Planning (East). DWAF Report No. P WMA 11/000/00/0304.

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

Department of Water Affairs (DWA), South Africa, September 2011. Classification of Significant Water Resources in the Mvoti to Umzimkulu Water Management Area (WMA 11): Scoping Report. Report No: RDM/WMA11/00/INT/CLA/0112.

Department of Water Affairs (DWA), South Africa, 2013a. Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Status quo assessment, IUA delineation and biophysical node identification. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. Report Number: RDM/WMA11/00/CON/CLA/0113.

Department of Water Affairs (DWA), South Africa, 2013b. Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Resource Units and EWR sites. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. Report Number: RDM/WMA11/00/CON/CLA/0213.

Department of Water Affairs, South Africa (DWA). 2013c. Assessment of the Present Ecological State (PES), Ecological Importance (EI) and Ecological Sensitivity (ES) for sub quaternary reaches in secondary drainage regions of South Africa. Department of Water Affairs, South Africa. In preparation.

GroundTruth Consultants. 2006. eThekwini Municipality - State of Rivers Report.

GroundTruth Consultants. 2010. Development of Camps Drift Canal: Aquatic Impact Assessment on the uMnsunduze at Camps Drift. Report Reference: GT0261-270111-01.

Hughes, DA, and Louw, D. 2010. Integrating hydrology, hydraulics and ecological response into a flexible approach to the determination of environmental water requirements for rivers. Environmental Modelling and Software 25: 910-918.

Hughes, DA, Louw, D, Desai, AY, Birkhead, AL. 2011. Development of a revised desktop model for the determination of the Ecological Reserve for Rivers. WRC report No 1856/1/11.

Iversen, TM, Madsen, BL, and Bøgestrand, J. 2000. River conservation in the European Community, including Scandinavia.In: "Global Perspectives on River Conservation: Science Policy and Practice", Edited by P.J. Boon, B.R. Davies and G.E. Petts, John Wiley & Sons Ltd.

IWR Source-to-Sea (eds). 2004. A Comprehensive Ecoclassification and Habitat Flow Stressor Response Manual. Prepared for IWQS: DWAF, Project no: 2002-148.

King, JM, and Louw, D. 1998. Instream flow assessments for regulated rivers in South Africa using the Building Block Methodology. Aquatic Ecosystem Health and Management 1: 109-124.

Kleynhans, CJ, Louw, MD, Thirion, C Rossouw, NJ, and Rowntree, K. 2005. River EcoClassification: Manual for EcoStatus determination (Version 1). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. KV 168/05.

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

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

Kleynhans, CJ and Louw, MD. 2007b. Module A: EcoClassification and EcoStatus determination in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT329-08.

Kleynhans, CJ, Mackenzie, J and Louw, MD. 2007. Module F: Riparian Vegetation Response Index. In River EcoClassification: Manual for EcoStatus Determination (version 2) Water Research Commission Report No. TT 333/08. Joint Water Research Commission and Department of Water Affairs and Forestry report, Pretoria, South Africa.

Kleynhans, CJ, Louw, MD, and Graham, M. 2009. Module G: EcoClassification and EcoStatus determination in River EcoClassification: Index of Habitat Integrity (Section 1, Technical manual) Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT330/08.

Louw, D, Kotze, P, and Mackenzie, J. 2010. Scoping study to identify priority areas for detailed EFR and other assessments. Produced for WRP as part of Support to Phase II ORASECOM Basin Wide Integrated Water Resources Management Plan.

Mucina, L. and Rutherford, M.C. (eds) (2006). The Vegetation of South Africa, Lesotho and Swaziland. Strelizia 19. South African National Biodiversity Institute, Pretoria.

Noss, RF. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology 4:355-364.

O'Keeffe, JH, Hughes, DA, and Tharme, R. 2002. Linking ecological responses to altered flows, for use in enviromental flow assessments: the Flow Stress-Response method. Proceedings of the International Association of Theoretical and Applied Limnology, 28, 84-92.

South African National Biodiversity Institute (SANBI), 2009. Plants of Southern Africa online database. Accessed through the SIBIS portal, sibis.sanbi.org.

Scott, LEP, Skelton, PH, Booth, AJ, Verheust, L, Harris, R and Dooley, J. 2006. Atlas of Southern African Freshwater Fishes. Smithiana Publication, Monograph 2. The South African Institute for Aquatic Biodiversity, Grahamstown, South Africa.

Skead, C. J. (compiler) (2009). Historical plant incidence in southern Africa. Strelizia 24. South African National Biodiversity Institute, Pretoria.

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

14 APPENDIX A: WATER QUALITY PRESENT STATE ASSESSMENT: RAPID EWR SITES

14.1 INTRODUCTION

The study area includes water resources in the Mvoti to Umzimkulu Water Management Area (WMA), i.e. WMA11. The report below covers the following steps per RAPID EWR site for the ecological water quality assessment:

- *Catchment context, particularly as it pertains to water quality.*
- *Available data/data confidence.*
- *Data assessment and Physico-chemical Driver Assessment Index (PAI) tables.*

14.1.1 Methods and approach

The methods and approach are not detailed in this document, but followed that outlined in DWAF (2008). Note that the following parameters were evaluated, with the associated summary statistic used for the assessment.

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

Water quality data were utilized in the following way: Nutrients, pH, chlorophyll-a, turbidity, DO, temperature and electrical conductivity data were compared to values in DWAF (2008), while all ionic data (i.e. macro-ions and salt ions) were compared to benchmark tables in DWAF (2008), the Target Water Quality Range (TWQR) guidelines of the South African aquatic ecosystem guidelines (DWAF, 1996a) where available, and relevant guidelines for recreational use (DWAF, 1996b). Diatom data were utilized as provided by the diatomologist for the study.

Data from other sources:

- *Umgeni Water (UW) data. Most sites have been monitored since 1990, but the last five years data (i.e. 2008 - 2013) were requested as being representative of present state. Note that all metals and ammonia data used in the assessments were sourced from Umgeni Water.*
- *eThekwini Municipality.*
- *Other sources.*
- *On-site water quality data, August 2013 – utilised in assessment where relevant.*

14.1.2 Setting the Reference Condition

The most critical part of a water quality assessment is setting Reference Condition (RC), or the natural state, as the change or deviation from RC defines the Present Ecological State (PES) or present state. As early water quality data were not often available, benchmark tables for an A category or natural/least impacted state were used as a proxy for RC.

14.2 DELINEATION AND EFR SITES

Information per EWR site in the study area is shown in Table 1.2 of the main report and additional water quality monitoring information is provided in Table 14.1.

Table 14.1 Additional water quality information per EWR site

EWR site name	River	RHP[1] site	Quat	Wq monitoring gauge (WMS code)	Umgeni Water site
Mg_R_EWR1	*uMngeni*	*U2MGEN-PETRU*	*U20A*	*U2H013 (WMS102628)*	*RMG001 at Petrus Stroom*
Mg_R_EWR3	*Karkloof*	*U2KARK-USMGN*	*U20E*	*U2H006 (WMS102624)*	*Karkloof C*
Mg_R_EWR4	*uMsunduze*	*U2DUZI-MOTOX*	*U20J*	*U2H041 (WMS102651)*	*RMD019 at Motocross*
Lo_R_EWR1	*Lovu*		*U70D*	*U7H007 (WMS102687)*	*RNW001; inflow to Nungwane Dam*
Mt_R_EWR1	*Mtamvuna*		*T40E*	*T4H001 (WMS102600)*	

1 River Health Programme

14.3 RESULTS

14.3.1 Mt_R_EWR1: Mtamvuna River

The Mtamvuna key area is a largely undeveloped catchment. The only significant water requirement is for domestic (both urban and rural areas) use, primarily for the coastal towns (e.g. Port Shepstone and Margate) which are mostly supplied through transfers from the Umzimkulu River (i.e. Port Shepstone). Other large towns include Port Edward and Izingolweni. There are large areas of dryland sugar cane in the catchment but the reduction in runoff due to this has little impact on the available yield because of its location along the coast. Irrigation in the catchment is insignificant. The Mtamvuna catchment therefore consists mostly of communal land which explains the large rural water requirement. There are also large areas of afforestation (DWAF, 2004a; cited in DWA, 2013a).

The PES of the SQ Mtamvuna River reach T40E-5601 where the EWR sites is located, is a B/C category, with the water quality assumed to be in a A/B to B category at a desktop level (DWA, 2013a).

The only water quality monitoring point in the area is on the Mtamvuna River and in the same Level II EcoRegion (i.e. 17.01) but well upstream of the EWR site, as can be seen in Figure 14.1. Data from this gauging weir, T4H001Q01 (WMS code 102600) (n = 403; 1978 - 2013) was used for the present state assessment.

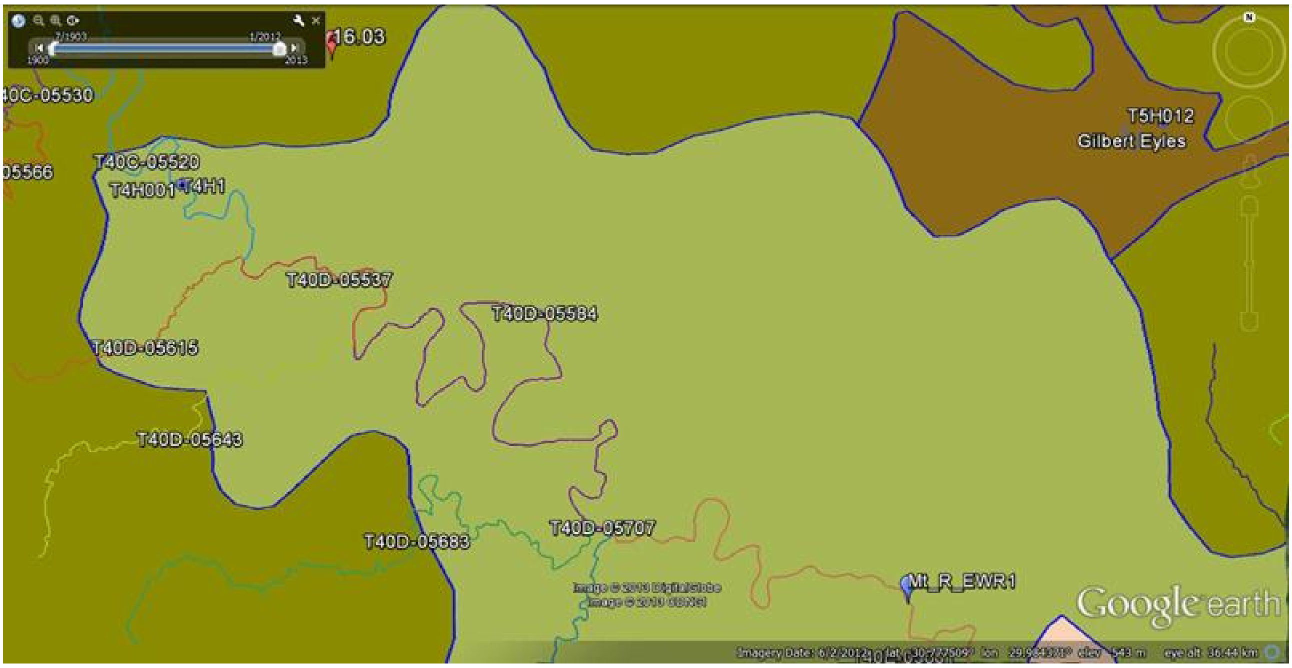

Figure 14.1 The position of EWR site Mt_R_EWR1

Reference Condition was represented by the A category benchmark tables in DWAF (2008). This was considered suitably representative of the natural state in the area.

This site was sampled for diatoms during June and August 2013. The diatom-based water quality was generally stable during these months and characterised by Good water quality, with an SPI score of 16.9, i.e. a B category (Appendix B).

Table 14.2 shows the water quality present state assessment for the site, and the PAI table is provided electronically.

Table 14.2 Water quality present state assessment for Mt_R_EWR1

Water Quality Constituents	PES Value	Category/Comment
Inorganic salt ions (mg/l)		
Sulphate as SO_4 Sodium as Na Magnesium as Mg Calcium as Ca Chloride as Cl Potassium as K	-	*Data not available, but salt assessment not triggered due to low electrical conductivity levels.*
Electrical conductivity (mS/m)	*13.1*	*A*
Nutrients (mg/l)		
SRP	*0.014*	*B*
TIN	*0.294*	*B*
Physical Variables		
pH (5^{th} + 95^{th} %ile)	*6.12 and 8.03*	*B*
Temperature (ºC)	-	*A. Natural temperature range expected.*
Dissolved oxygen (mg/L)	-	*A/B. Some man-made modifications in the catchment, but an almost natural oxygen range expected.*
Turbidity (NTU)	-	*B. Land-use activities are expected to result in increased turbidity levels at times.*

Water Quality Constituents	PES Value	Category/Comment
Response variables		
Chl-a: phytoplankton (ug/L)	*-*	
Macro-invertebrate score (MIRAI) *SASS score* *ASPT score*	*84.2%* *159* *8*	*B*
Diatoms	*SPI=16.9 (n = 2)*	*B*
Fish score (FRAI)	*80.8%*	*B/C*
Toxics		
Fluoride (as mg/l F)	*0.022*	*A*
Microbial indicator (counts/100 ml): E. coli	*-*	*-*
OVERALL SITE CLASSIFICATION (PAI model)		**A/B (88.6%)**

- no data

Water quality is in an A/B category for this site. Although certain data are lacking, the confidence in the assessment is estimated to be MODERATE, largely due to the simplicity of the catchment and limited land-use.

14.3.2 Lo_R_EWR1: Lovu River

Sugarcane plantations (irrigation) and forestry (afforestation), including informal cattle farming, are the predominant land uses in the Lovu catchment, with Richmond and Amanzimtoti representing the main urban land use areas. Two of the smaller Mgwahumbe SQ catchments are however still largely natural. E. coli, phosphates (SRP, i.e. Soluble Reactive Phosphate) and turbidity are problematic in the catchment, which is probably due to livestock farming, intensive sugarcane farming (Umgeni Water, 2011; 2012; cited in DWA, 2013a), sand mining and inefficient Waste Water Treatment Works (WWTWs). A summary of wastewater impacts are therefore as follows (DWA, 2013b):

- *Non-point source pollution (pesticides, fertilizers, elevated salt and nutrient levels) from agriculture (mostly sugarcane plantations).*
- *Non-point source pollution from residential areas (urban and rural townships) e.g. stormwater run-off, washing in rivers.*
- *Point source pollution from industrial discharge points (sugar and paper mills etc.) and urban infrastructure (e.g. sewage, wastewater treatment works non-compliance).*
- *Sand mining activities, with concomitant erosion and sedimentation problems resulting in high turbidity. Erosion and sedimentation has been raised as an issue in the catchment (Umgeni Water, 2011; cited in DWA, 2013a).*
- *E. coli, SRP and turbidity are problematic in the catchment, which is probably due to livestock farming (E .coli), intensive sugarcane plantations (Umgeni Water, 2011; 2012; cited in DWA, 2013a), sand mining, sewage discharge and overgrazing.*
- *The presence of alien invasive plants within the riparian zone of rivers due to the removal of indigenous vegetation for agriculture and sand mining. In-stream dams are scattered throughout the catchment, which impact on the movement of sediment, temperature and oxygen levels in particular.*

The PES of the SQ Lovu River reach U70C-04859 where the EWR sites is located, is a B/C category, with the water quality assumed to be in a A/B to B category at a desktop level (DWA, 2013a).

There are only two active water quality gauging weirs in the U7 catchment area which contains the Lovu River. The EWR site is in quaternary catchment U70D and Level II EcoRegion 17.01.

- *U7H007Q01 (WMS code 102687) on the Lovu River at Beaulieu Estate in U70B upstream of Richmond and well upstream of the EWR site in Level II EcoRegion 16.03. Samples have been collected from 1977 to 2013 (n=445).*
- *U7H008Q01 (WMS code 102688) on the downstream weir of the Nungwane Dam on the Nungwane River in U70D. Samples have been collected from 1990 – 2013; n = 1 453; Level II EcoRegion 17.01.*

There are also two UW sites on the Nungwane River; one at the inflow to the dam and one at the outflow to the dam. Data from the INFLOW site was also used for the Lovu River assessment (i.e. UW site RNW001) (n = 59; metals: n = ± 4). Reference Condition was represented by the A category benchmark tables in DWAF (2008). This was considered suitably representative of the natural state in the area.

Figure 14.2 shows the proximity of the EWR site to the UW sites and D7H008 gauging weir in Level II EcoRegion 17.01.

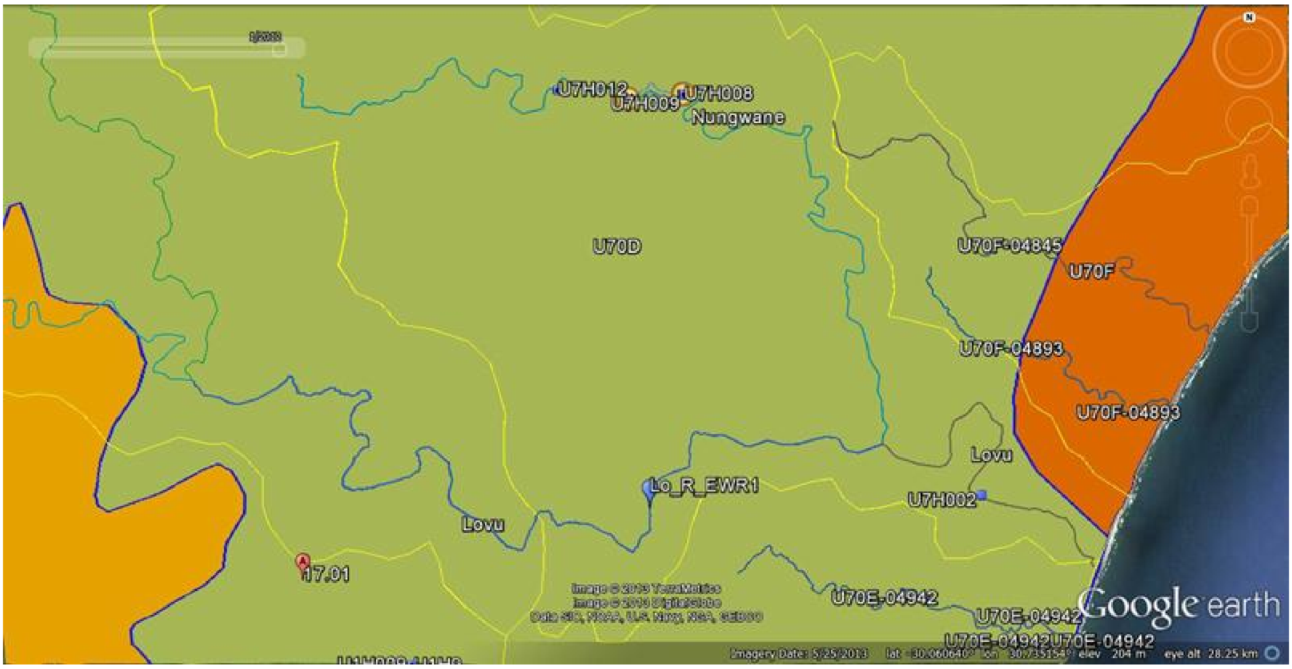

Figure 14.2 The position of EWR site Lo_R_EWR1

Reference Condition was represented by the A category benchmark tables in DWAF (2008). This was considered suitably representative of the natural state in the area.

Diatom results indicated that the SPI score remained relatively stable, with a SPI score of 14.6 and 14.7, i.e. a B/C Ecological Category during this period. The diatom community present indicated that nutrient and organic pollution levels were increasing to potentially problematic levels. What was of concern were valve deformities present in the diatoms seen at the site, particularly during the August survey. These indicate metal toxicity.

Table 14.3 shows the water quality present state assessment for the site, and the PAI table is provided electronically.

Table 14.3 Water quality present state assessment for Lo_R_EWR1

Water Quality Constituents	PES Value	Category/Comment
Inorganic salt ions (mg/l)		
Sulphate as SO_4 Sodium as Na Magnesium as Mg Calcium as Ca Chloride as Cl Potassium as K	-	*Data not available, but salt assessment not triggered due to low electrical conductivity levels.*
Electrical conductivity (mS/m)	*13.9: UW 10.6: DWA*	*A*
Nutrients (mg/l)		
SRP	*0.005: UW 0.011: DWA*	*B*
TIN (only NO_3-N for UW)	*1.62: UW 0.34: DWA*	*C. Result indicates some pollution of both systems, but particularly the Nungwane River.*
Physical Variables		
pH (5^{th} + 95^{th} %ile)	*7.5 and 8.4: UW 6.11 and 7.84: DWA*	*B*
Temperature (ºC)	*Median: 18.7 (UW)*	*A. Natural temperature range expected.*
Dissolved oxygen (mg/L)	-	*A/B. Man-made modifications to the catchment, but few impacts expected.*
Turbidity (NTU) (UW data only)	*Median: 10.1 Mean: 12.9 Max: 77.4*	*B. Sand-mining and agricultural activities in the catchment are expected to have some impact on the system.*
Response variables		
Chl-a: phytoplankton (ug/L)	-	
Macro-invertebrate score (MIRAI) SASS score ASPT score	*80.6% 143 6.8*	*B/C*
Diatoms	*SPI = 14.6 (n = 2)*	*B/C*
Fish score (FRAI)	*78.9%*	*B/C*
Toxics		
Fluoride (as mg/l F)	*0.05: UW 0.23: DWA*	*A*
Ammonia (as mg/l N)	*1.08*	*F*
Copper (as mg/l Cu)	*0.025*	*F*
Manganese (as mg/l Mn)	*0.04*	*Within the aquatic ecosystem TWQR (DWAF, 1996a).*
Zinc (as mg/l Zn)	*0.015*	*Exceeds the aquatic ecosystem guidelines (DWAF, 1996a).*
As	*1*	*A*
Cn	*5*	*B*
Cd	*0.5*	*B*
Al	*239*	*F*
Cr	*5.07*	*A*
Pb	*2*	*B*
Se	*1*	*A*
Microbial indicator (counts/100 ml): E. coli	*Median: 450 Mean: 812 Max: 11 300*	*The mean value exceeds the TWQR of 0 - 130 counts/100ml (DWAF, 1996a) for full-contact recreational use.*

Water Quality Constituents	PES Value	Category/Comment
OVERALL SITE CLASSIFICATION (PAI model)		**B/C (80.4%)**

- no data

Water quality is in an A/B category for this site. Although certain data are lacking, the confidence in the assessment is estimated to be MODERATE, largely due to the simplicity of the catchment and limited land-use.

14.3.3 Mg_R_EWR1: uMngeni River

Flow regulation in the uMngeni catchment via the Midmar, Albert Falls, Nagle and Inanda dams, has an important impact on the quality of the system. It alters sediment transport and nutrients, resulting in an enhancement of cyanobacterial growth. However, water quality upstream of Midmar Dam is in a relatively good state, with the main water quality related impacts being agricultural runoff and livestock farming. The PES of the SQ reach U20A-04253 where the EWR site is located, is a B/C category, with the water quality assumed to be in an A/B to B category at a desktop level (DWA, 2013b).

Figure 14.3 shows the position of the site in relation to Midmar Dam, the Umgeni Water site and the gauging weir.

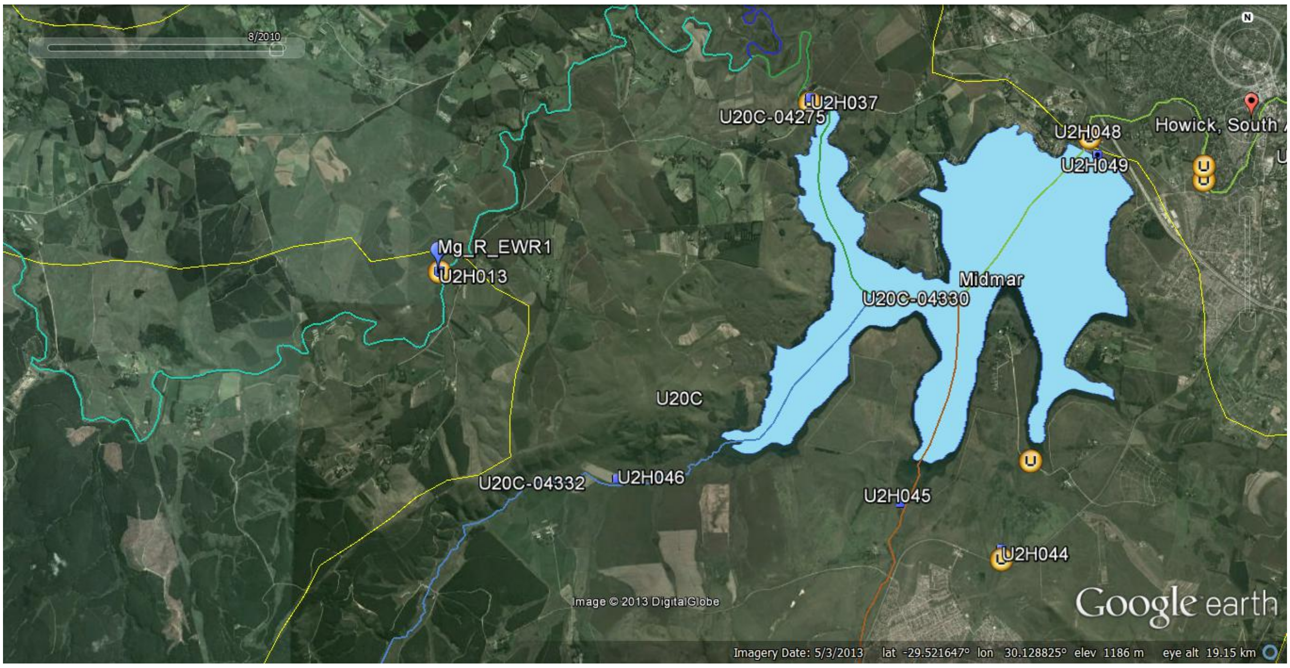

Figure 14.3 The position of EWR site Mg_R_EWR1

The gauging weir, U2H013Q001 and both the EWR site and Umgeni Water sampling site, RMG001, are all at the same geographical position. Note that the data record for the gauging weir is from 1977 - 1995, while Umgeni Water data are available from 2008 – 2013 (n = 60). The latter data were therefore used to represent present state. Reference Condition was represented by the A category benchmark tables in DWAF (2008). This was considered suitably representative of the natural state in the area.

The diatom analysis (n = 1, June 2013) indicated that the biological water quality at this site was Good with a SPI score of 17.8 (i.e. an A/B Ecological Category). The diatom community consisted *generally of species preferring good water quality conditions, however the outright dominance of A. crassum limited accurate ecological interpretation. Gomphonema species were sub-dominant indicating that organic pollution levels were present but not problematic. Diatom community structure also indicates that nutrient and salinity levels were elevated but not problematic (Appendix B).*

Table 14.4 therefore shows the water quality present state assessment for the site, and the PAI tables are provided electronically.

Table 14.4 Water quality present state assessment for Mg_R_EWR1

Water Quality Constituents	PES Value	Category/Comment
Inorganic salt ions (mg/l)		
Sulphate as SO_4 Sodium as Na Magnesium as Mg Calcium as Ca Chloride as Cl Potassium as K	-	*Data not available, but salt assessment not triggered due to low electrical conductivity levels.*
Electrical conductivity (mS/m)	*7.47*	*A*
Nutrients (mg/l)		
SRP	*0.004*	*A*
TIN	*0.21*	*A*
Physical Variables		
pH (5^{th} + 95^{th} %ile)	*6.8 and 8.5*	*B*
Temperature (ºC)	*Median: 17*	*Natural temperature range expected.*
Dissolved oxygen (mg/L)	*6.9*	*B. Some man-made modifications in the catchment but no known problems or concerns about DO.*
Turbidity (NTU)	*Median: 6.7 Mean: 10.9 Max: 55.7*	*A/B. Changes in turbidity appear to be largely related to natural with minor man-made modifications.*
Response variables		
Chl-a: phytoplankton (ug/L)	-	
Macro-invertebrate score (MIRAI) SASS score ASPT score	*69.8% 61 4.7*	*C*
Diatoms	*SPI=17.8 (n = 1)*	*A/B*
Fish score (FRAI)	*38.3%*	*D/E*
Toxics		
Ammonia (as N)	*0.091*	*C*
Microbial indicator (counts/100 ml): E. coli	*Median: 160 Mean: 320 Max: 2 850*	*The mean value exceeds the TWQR of 0 - 130 counts/100 ml (DWAF, 1996a) for full-contact recreational use.*
OVERALL SITE CLASSIFICATION (PAI model)		**B (87.4%)**

- no data

The present state category for water quality is a B category, with a MODERATE confidence as no reference condition data were available for use. There is moderate to high confidence in the present state data, although little data exists for toxics.

14.3.4 Mg_R_EWR3: Karkloof River

This site is on the Karkloof River (Level II EcoRegion 16.03), which is a tributary coming into the uMngeni River between Midmar and Albert Falls dams. The upper Karkloof is dominated by commercial forestry with agriculture (irrigation) in the lower section towards the Karkloof Waterfall. Downstream of the waterfall, the river falls within a private nature reserve and although protected, barriers and inundation of small dams built prior to the existence of the Reserve are a serious problem (DWA, 2013b).

The PES of the SQ reach U20E-04170 where the EWR site is located, is a B/C category, with the water quality assumed to be in an A/B to B category at a desktop level. The PES of the upper forestry regions is in a C PES (DWA, 2013a).

Figure 14.4 shows the position of the site in relation to the water quality monitoring point upstream of the Karkloof Falls, i.e. U2H006Q01 in Level II EcoRegion 16.01.

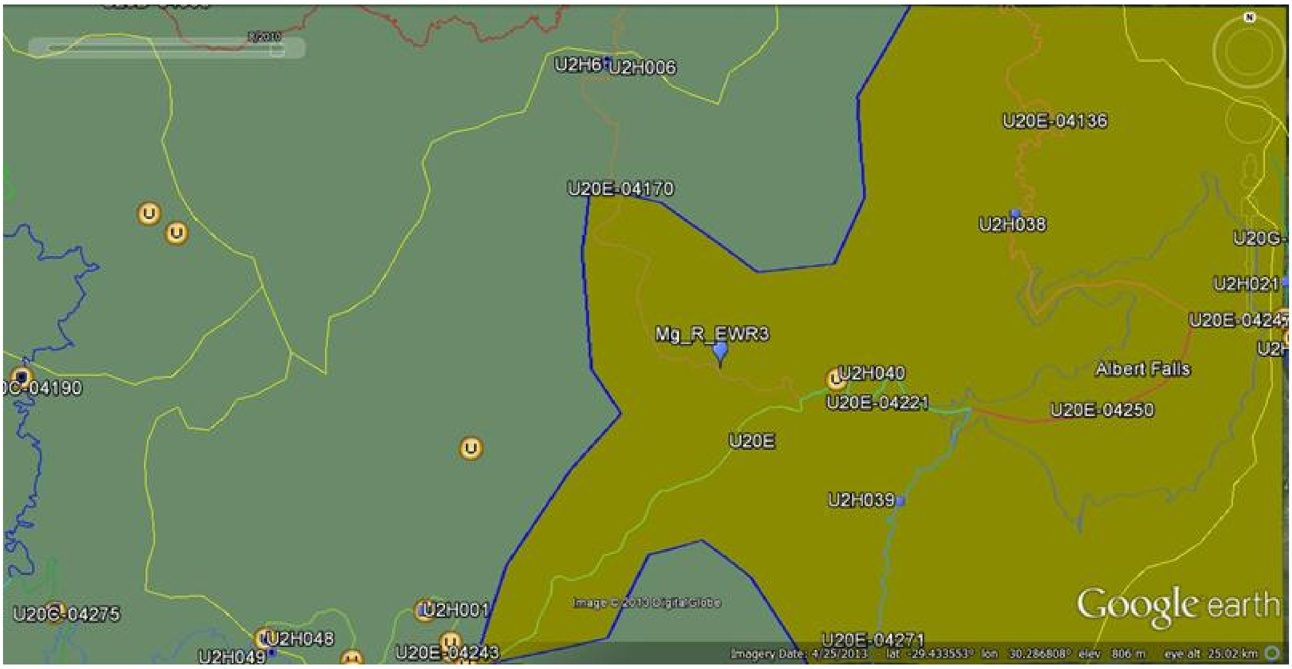

Figure 14.4 The position of EWR site Mg_R_EWR3

There is no UW site on the Karkloof River, with the only DWA gauging weir being well upstream in a different Level II EcoRegion (see Figure 7.4). The data record for this gauging weir, i.e. U2H006Q01 (WMS code 102624), is from 1970 - 2013, with 903 data records. Data used for the present state assessment was therefore from 2008 – 2013 (n = 60+; F: n = 50). Reference Condition was represented by the A category benchmark tables in DWAF (2008). This was considered suitably representative of the natural state in the area.

The diatom-based water quality deteriorated slightly below the waterfall. The sample above the Karfkloof Falls was an SPI of 15.6, with the SPI score at the EWR site being 16.4 (n = 1, August 2013). Although the water quality was still good the diatoms indicate an increased gradient in nutrient loading downstream of the waterfall as reflected by the increased abundance of Cocconeis species. Nutrient levels were however not problematic as Navicula cymbula was also dominant and generally sensitive to deteriorated water quality and an indicator species of good water quality conditions (Appendix B).

Table 14.5 therefore shows the water quality present state assessment for the site, and the PAI tables are provided electronically.

Table 14.5 Water quality present state assessment for Mg_R_EWR3

Water Quality Constituents	PES Value	Category/Comment
Inorganic salt ions (mg/l)		
Sulphate as SO_4 *Sodium as Na* *Magnesium as Mg* *Calcium as Ca* *Chloride as Cl* *Potassium as K*	-	*Data not available, but salt assessment not triggered due to low electrical conductivity levels.*
Electrical conductivity (mS/m)	*14.1*	*A*
Nutrients (mg/l)		
SRP	*0.005*	*B*
TIN	*0.39*	*B*
Physical Variables		
pH (5^{th} + 95^{th} %ile)	*7.0 and 8.0*	*A*
Temperature (ºC)	-	*A/B. Largely natural temperature range expected.*
Dissolved oxygen (mg/L)	-	*B. Downstream a waterfall, so oxygen problems not expected. However, numerous small dams in lower reaches.*
Turbidity (NTU)	-	*B. Changes in turbidity appear to be largely related to natural with minor man-made modifications.*
Response variables		
Chl-a: phytoplankton (ug/L)	-	
Macro-invertebrate score (MIRAI) *SASS score* *ASPT score*	*85.4%* *106* *6.6*	*B*
Diatoms	*SPI=16.4 (n = 1)*	*B*
Fish score (FRAI)	*79.5%*	*B/C*
Toxics		
Fluoride (as F)	*0.0484*	*A*
Microbial indicator (counts/100 ml): E. coli	-	
OVERALL SITE CLASSIFICATION (PAI model)		**B (86.4%)**

- no data

The present state category for water quality is a B category, with a LOW confidence as no reference condition data were available and the water quality monitoring site is not within the same Level II EcoRegion as the EWR site. It is however assumed that the PAI table is a fair reflection of water quality at the site.

14.3.5 Mg_R_EWR4: uMnsunduze River

The EWR site is found on the uMnsunduze River upstream of the confluence with the uMngeni River below Nagle Dam. The uMnsunduze River flows eastwards to Henley Dam, Edendale and Pietermaritzburg (WRC, 2002; cited in DWA, 2013a). The uMsunduze River catchment upstream of Pietermarizburg has moderate to serious erosion problems, especially in the Henley Dam catchment. Serious faecal (sewer reticulation and inadequate on-site latrine problems) and general *urban pollution arises from Pietermaritzburg, with potentially very serious industrial pollution and significant nutrient enrichment (DWAF, 2004a; cited in DWA, 2013a).*

The water quality in the uMnsunduze downstream of Henley Dam is seriously affected by sewer infrastructure problems, including ingress of rainwater into the sewer system which results in surcharges overloading Darville WWTW. Pit latrines are also extensively used in the area. The Darvill WWTW is the single most important contributor of nutrients to the downstream system, with poorly managed subsistence agriculture, overgrazing and poor sanitation systems downstream (WRC, 2002; cited in DWA, 2013a). The water quality of the middle and lower uMnsunduze is very poor, with a high faecal coliform content and nutrient enrichment, resulting in significant risks of health effect if the water is used for drinking and contact recreation, e.g. the annual Dusi canoe marathon. The nutrient concentrations in the lower uMsunduze River are also very high and contribute significantly to the eutrophication processes of the lower Mgeni River (DWA, 2013a).

Figure 14.5 shows the position of the EWR site downstream of Pietermaritzburg and the Darville WWTW, and the inflow of Baynespruit.

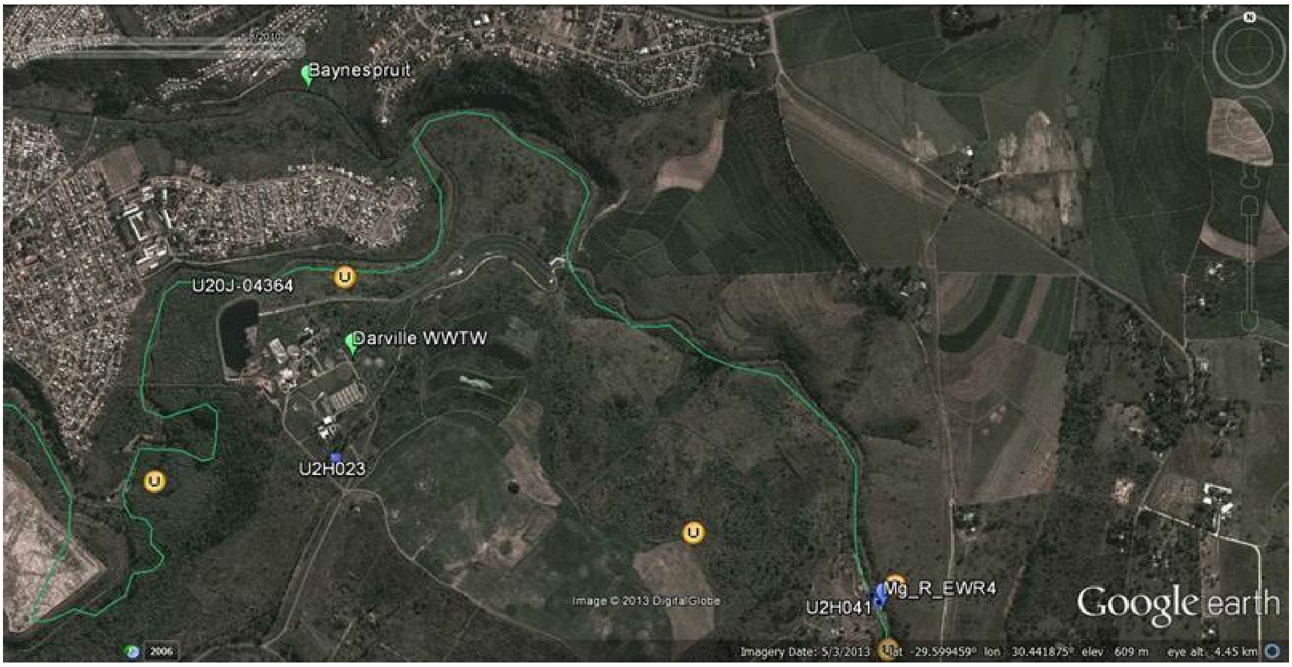

Figure 14.5 The position of EWR site Mg_R_EWR4

Note that Darville WWTW was categorized as a Low Risk works in the DWA 2012 Green Drop Report. Baynespruit is reportedly of very poor quality as it runs through the Pietermaritzburg industrial area. An UW site is located on this river.

The PES of the sub-quaternary (SQ) reach U20J-04364 where the EWR sites is located, is a D/E category, with the water quality assumed to be in a D/E to an E category at a desktop level (DWA, 2013a).

The gauging weir, U2H041Q001 (Msunduze River @ Hamstead Park) and both the EWR site and Umgeni Water sampling site, RMD019 (Duzi at Motocross), are all at the same geographical position downstream of Pietermaritzburg and Darville WWTW. Note that the data record for the gauging weir is from 1985 - 2013 (n = 2 046), while Umgeni Water data are available from 2008 - 2013. Both data sources were used to represent present state:

- *DWA site U2H041, WMS code 102651: n = 115+; 2008 - 2013; F: n = 54*
- *UW site RMD019, n = 50+; metals: n = ± 20*

Reference Condition was represented by the A category benchmark tables in DWAF (2008). This was considered suitably representative of the natural state in the area.

The diatom-based water quality score indicated Poor quality water with a SPI score of 5, i.e. an E category (n = 1, August 2013). Nutrient levels were elevated and problematic while salinity levels were also elevated at the time of sampling. Organic pollution levels were unacceptably high. Dominant diatom species present have a preference for anthropogenically impacted waters with high organic loads and diatom indicator species for industrial related impact were present at various abundances. The diatom community indicated that very heavy pollution levels were present for prolonged periods of time not allowing for system recovery, as a clear cycle of primary and secondary succession was not evident within the community. Of concern was the occurrence of diatom valve deformities which relates to the presence of metal toxicity (Appendix B).

Table 14.6 therefore shows the water quality present state assessment for the site, and the PAI tables are provided electronically.

Table 14.6 Water quality present state assessment for Mg_R_EWR4

Water Quality Constituents	PES Value	Category/Comment
Inorganic salt ions (mg/l)		
Sulphate as SO_4 Sodium as Na Magnesium as Mg Calcium as Ca Chloride as Cl Potassium as K	-	*Data not available, but salt assessment not triggered due to low electrical conductivity levels.*
Electrical conductivity (mS/m)	*46.7: UW 44.3: DWA*	*B*
Nutrients (mg/l)		
SRP	*0.091: UW 0.026: DWA*	*D*
TIN (only NO_3-N for UW)	*1.36: UW 2.12: DWA*	*D*
Physical Variables		
pH (5^{th} + 95^{th} %ile)	*7.1 and 8.1: UW 7.0 and 8.2: DWA*	*A/B*
Temperature (ºC)	*Median: 19.8 (UW)*	*B/C: Minor to moderate changes in temperature expected due to upstream impacts.*
Dissolved oxygen (mg/L)	*4.9: UW*	*D*
Turbidity (NTU) (UW data only)	*Median: 27.7 Mean: 62.8 Max: 913*	*B/C: Changes to the catchment will result in increased turbidity levels at times.*
Response variables		
Chl-a: phytoplankton (ug/L)	-	
Macro-invertebrate score (MIRAI) SASS score ASPT score	*35% 106 6.6*	*E*
Diatoms	*SPI=5 (n = 1)*	*E*
Fish score (FRAI)	*37.1%*	*E*

Water Quality Constituents	PES Value	Category/Comment
Toxics		
Fluoride (as F)	*0.137: UW* *0.513: DWA*	*A*
Ammonia (as mg/l N)	*6.8*	*F*
Copper (as mg/l Cu)	*0.031*	*F*
Iron (as mg/l Fe)	*1.59*	*TWQR: Fluctuation of less that 10% (DWAF, 1996a).*
Manganese (as mg/l Mn)	*0.22*	*Exceed aquatic ecosystem TWQR (DWAF, 1996a).*
Zinc (as mg/l Zn)	*0.041*	*Exceed aquatic ecosystem guidelines (DWAF, 1996a).*
As	*1*	*A*
CN	*32.4*	*B*
Cd	*0.83*	*B*
Al	*1 282*	*F*
Cr	*6.85*	*A*
*Pb **	*4.5*	*B/C*
Se	*1*	*A*
Phenols	*2.5*	*A*
Microbial indicator (counts/100 ml): E. coli	*Median: 3 500* *Mean: 12 901* *Max: 308 000*	*The mean value exceeds the TWQR of 0 - 130 counts/100ml (DWAF, 1996a) for full-contact recreational use.*
OVERALL SITE CLASSIFICATION (PAI model)		**E/F (20.0%)**

- no data
** water hardness unknown; assumed to be moderate.*

The present state category for water quality is an E/F category, primarily because the threshold for oxygen (i.e. a D category, or rating of >3, i.e. oxygen levels of 4 - 6 mg/l) was exceeded. Both DWA and UW data were available for this assessment, although data counts for metals were low. The overall confidence for the assessment is considered to be MODERATE to HIGH.

14.4 REFERENCES

Department of Water Affairs and Forestry (DWAF). 1996a. South African water quality guidelines. Volume 7: Aquatic Ecosystems.

Department of Water Affairs and Forestry (DWAF). 1996a. South African water quality guidelines. Volume 2: Recreational use.

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

Department of Water Affairs (DWA), South Africa, 2013a. Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Status quo assessment, IUA delineation and biophysical node identification. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. Report Number: RDM/WMA11/00/CON/CLA/0113.

Department of Water Affairs (DWA), South Africa, 2013b. Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Resource Units and EWR sites. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. Report Number: RDM/WMA11/00/CON/CLA/0213.

15 APPENDIX B: DIATOM RESULTS

15.1 INTRODUCTION

Benthic diatoms were used in this study as indicators of biological water quality. Diatoms typically reflect water quality conditions over the past three days and are ecologically important because of their role as primary producers, which form the base of the aquatic food web, and because they usually account for the highest number of species among the primary producers in aquatic systems (Leira and Sabater 2005). Diatoms are photosynthetic unicellular organisms and are found in almost all aquatic and semi-aquatic habitats. They have been shown to be reliable indicators of specific water quality problems such as organic pollution, eutrophication, acidification and metal pollution (Tilman et al. 1982, Dixit et al. 1992, Cattaneo et al. 2004), as well as for general water quality (AFNOR, 2000).

15.2 TERMINOLOGY

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

Trophy	
Dystrophic	*Rich in organic matter, usually in the form of suspended plant colloids, but of a low nutrient content.*
Oligotrophic	*Low levels or primary productivity, containing low levels of mineral nutrients required by plants.*
Mesotrophic	*Intermediate levels of primary productivity, with intermediate levels of mineral nutrients required by plants.*
Eutrophic	*High primary productivity, rich in mineral nutrients required by plants.*
Hypereutrophic	*Very high primary productivity, constantly elevated supply of mineral nutrients required by plants.*
Mineral content	
Very electrolyte poor	*< 50 µS/cm*
Electrolyte-poor (low electrolyte content)	*50 - 100 µS/cm*
Moderate electrolyte content	*100 - 500 µS/cm*
Electrolyte-rich (high electrolyte content)	*> 500 µS/cm*
Brackish (very high electrolyte content)	*> 1000 µS/cm*
Saline	*6000 µS/cm*
Pollution (Saprobity)	
Unpolluted to slightly polluted	*BOD <2, O_2 deficit <15% (oligosaprobic)*
Moderately polluted	*BOD <4, O_2 deficit <30% (β-mesosaprobic)*
Critical level of pollution	*BOD <7 (10), O_2 deficit <50% (β-ά-mesosaprobic)*
Strongly polluted	*BOD <13, O_2 deficit <75% (ά-mesosaprobic)*
Very heavily polluted	*BOD <22, O_2 deficit <90% (ά-meso-polysaprobic)*
Extremely polluted	*BOD >22, O_2 deficit >90% (polysaprobic)*

15.3 METHODS

15.3.1 Sampling

Sampling methods were followed as outlined in Taylor et al. (2007a) which were designed and refined as part of the Diatom Assessment Protocol, a Water Research Commission initiative. Five Rapid EWR sites were sampled during June and August 2013 respectively.

15.3.2 Slide preparation and diatom enumeration

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

15.3.3 Diatom-based water quality indices

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

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

15.3.4 Data analysis

Diatom-based water quality score

The European numerical diatom index, the Specific Pollution sensitivity Index (SPI) was used to interpret results. De la Rey et al. (2004) concluded that the SPI reflects certain elements of water quality with a high degree of accuracy due to the broad species base of the SPI. The interpretation of the SPI scores was adjusted during 2011 (Taylor and Koekemoer, in press) and the new adjusted class limits are provided in Table 15.1. The new adjustments will affect diatom-derived Ecological Categories from previous studies and therefore all previous results have been adjusted accordingly.

Table 15.1 Adjusted class limit boundaries for the SPI index applied in this study

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

Diatom based Ecological classification

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

Valve deformities

According to Luís et al. (2008) several studies on metal polluted rivers have shown that diatoms respond to perturbations not only at the community but also at the individual level with alteration in cell wall morphology. In particular, size reduction and frustule deformations have been sometimes associated with high metal concentrations. The general threshold for the occurrence of valve deformities in a sample is usually considered between 1 - 2% and is regarded as potentially hazardous (Taylor, pers. comm.).

15.4 RESULTS

A summary of the diatom results are provided in Table 15.2 and include the presence of PTVs and percentage valve deformities based on a total count of 400 diatom valves. The diatom based ecological classification based on Van Dam et al. (1994) for diatom-based water quality is given in Table 15.3.

Table 15.2 Diatom analysis results for Mvoti EWR Rapid sites

Date	Site	No species	SPI score	Class	Category	PTV (%)	Deformities (%)
Jun 13	Mt_R_EWR1	8	16.3	Good quality	B	0	0
Aug 13	Mt_R_EWR1	28	17.7	High quality	A/B	3.3	0
Jun 13	Lo_R_EWR1	19	14.6	Good quality	B/C	0.3	1
Aug 13	Lo_R_EWR1	24	14.7	Good quality	B/C	3.8	5.25
Jun 13	Mg_R_EWR1	19	17.8	High quality	A/B	0	0.5
Jun 13	Mg_R_EWR3	28	15.6	Good quality	B	8.8	0.75
Aug 13	Mg_R_EWR3	19	16.4	Good quality	B	2.3	0.75
Aug 13	Mg_R_EWR4	29	5	Bad quality	E	77.3	1

Table 15.3 Generic diatom based ecological classification for Mvoti EWR Rapid sites

Date	Site	pH	Salinity	Organic nitrogen	Oxygen levels	Pollution levels	Trophic status
Jun 13	Mt_R_EWR1	Circumneutral	Fresh	Small concentrations of organically bound nitrogen	Continuously high (~100% saturation)	Unpolluted to slightly polluted	Indifferent
Aug 13	Mt_R_EWR1	Circumneutral	Fresh	Elevated concentrations of organically bound nitrogen	Continuously high (~100% saturation)	Moderately polluted	Indifferent
Jun 13	Lo_R_EWR1	Alkaline	Fresh brackish	Elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Moderately polluted	Eutrophic
Aug 13	Lo_R_EWR1	Circumneutral	Fresh brackish	Elevated concentrations of organically bound nitrogen	Very low (~10% saturation)	Moderately polluted	Eutrophic
Jun 13	Mg_R_EWR1	Circumneutral	Fresh brackish	Elevated concentrations of organically bound nitrogen	Continuously high (~100% saturation)	Moderately polluted	Indifferent
Jun 13	Mg_R_EWR3	Circumneutral	Fresh	Elevated concentrations of	Continuously high	Moderately	Eutrophic

Date	Site	pH	Salinity	Organic nitrogen	Oxygen levels	Pollution levels	Trophic status
			brackish	organically bound nitrogen	(~100% saturation)	polluted	
Aug 13	Mg_R_EWR3	Alkaline	Fresh brackish	Elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Moderately polluted	Eutrophic
Aug 13	Mg_R_EWR4	Circumneutral	Fresh brackish	Periodically elevated concentrations of organically bound nitrogen	Low (>30% saturation)	Very heavily polluted	Eutrophic

15.5 DISCUSSION

The results of the diatom analyses are provided below. Note: Species contributing 5% or more to the total count were classified as dominant species. A species list is provided electronically.

15.5.1 Mt_R_EWR1: Mtamvuna River

This site was sampled during June and August 2013. The diatom-based water quality was generally stable during these months and characterised by good water quality. Nutrient levels and salinity levels were low during June 2013 but there was a notable increase in these levels during August. Organic pollution levels followed the same trend. However the deteriorated levels still were within the boundaries that classifies the water as good quality. The greatest abundance of species were from the genus Achnanthidium and included A. crassum, A. minutissimum and A. lineare which have an affinity for good water quality with high oxygenation rates. There was an general increase in abundance of species for a preference for moderate water quality indicating that the biological water quality did deteriorate to some extent during August although not reflected by the SPI score. The species diversity, due to the dominance of Achnanthidium species, was very low during June 2013, making ecological interpretation difficult.

The SQ reach was generally in a B/C Ecological Category due to impacts that included sedimentation, dryland sugar cane cultivation and overgrazing. Based on the limited diatom information available for the Mtamvuna River the PES for biological water quality was determined to be a B.

15.5.2 Lo_R_EWR1: Lovu River

The site was sampled during June and August 2013. The diatom results indicated that the SPI remained stable at a B/C EC (Table 15.2) during this period. Salinity levels were elevated to the extent of becoming problematic during June 2013 but decreased during August 2013. Although the diatom classification (Table 15.3) indicated that overall nutrient levels improved between June and August 2013, the diatom community indicated that nutrient levels were increasing to potentially problematic levels. Organic pollution levels followed the same trend as reflected in the increase in PTVs (Table 15.2). This was most probably not reflected by the overall ecological classification as the diatoms were in a state of flux. Dominant species included Cocconeis species, A. crassum and E. leei var. sinensis. The abundance of Achnanthidium species was generally higher during August 2013 indicating that flows were higher than during June 2013, and these conditions could account for increasing levels of nutrients and organics originating upstream of the site. Diatom indicator species for anthropogenic impact (particularly industrial activities) were present during both samples and the diatom community was generally characteristic of anthropogenically impacted waters.

Valve deformities were within the thresholds with an occurrence of 1% during June 2013. However valve deformities increased drastically during August 2013 and at an occurrence of 5.25% exceeded thresholds and would have an adverse effect on the biotic functioning of the river. The *water quality analysis (Appendix A) found that metal ions were present in the Nungwane River. The deteriorated state of this tributary may be impacting the Lovu River negatively. In close proximity to the site there is a road that runs through the river and the area is used for washing cars. These activities may also contribute to elevated metal toxicity in the river.*

According to DWA (2013) the major impacts in SQ U70C-04859 were rural settlements, subsistence farming and cattle grazing and the overall PES for the reach was a B/C. One diatom sample collected at the Lovu Sugar Estate as part of the eThekwini Municipality - State of Rivers Report (GroundTruth, 2006) indicated that the biological water quality in the love River downstream of the EWR site was Fair (SPI score: 9 – 13). Based on available information the diatom-based water quality was determined to be in a C Ecological Category. The main variables of concern were salinity and nutrients. The high occurrence of metal toxicity was also a great concern and at unacceptable levels, especially during August 2013.

15.5.3 Mg_R_EWR1: uMngeni River

The biological water quality at this site was high with a SPI score of 17.8 (A/B Ecological Category) (Table 15.2). The dominant species Achnanthidium crassum had a dominance of 73% and has an affinity for slow flowing alkaline waters. A. minutissima was also dominant and occurs in a wide variety of habitats but prefers well oxygenated clean waters (Taylor et al., 2007b). Encyonopsis leei var. sinensis was also dominant and is generally found in oligo- to mesotrophic waters with low to moderate electrolyte content (Taylor et al., 2007b). The diatom community consisted generally of species preferring good water quality conditions. Gomphonema species were sub-dominant indicating that organic pollution levels were present but not problematic as no PTVs were observed. Nutrient and salinity levels were elevated but not problematic.

According to DWA (2013) the major water quality related impacts were agricultural runoff and livestock farming and the PES of the SQ reach U20A-04253 was a B/C. Based on available information the diatom-based water quality EC was determined to be a B.

15.5.4 Mg_R_EWR3: Karkloof River

The results of the sample collected during June 2013 represent biological water quality conditions upstream of the waterfall in the Karkloof River. The sample collected during August 2013 was collected downstream of the waterfall.

The diatom-based water quality conditions upstream of the waterfall during June 2013 were good with a SPI score of 15.6 as reflected by the dominance of E. leei var. sinensis and Encyonmena minutum. Salinity and nutrient levels were low while organic pollution levels were elevated with PTVs making up 8% of the total count and reflected by the dominance of Gomphonema parvulum and sub-dominance of Navicula germainii which is tolerant to critical levels of pollution. Cocconeis placentula was however also dominant and indicated that nutrient levels could become problematic at times. The genus Cocconeis has a broad ecological range and is found in most running waters except where nutrients are low or acidic conditions prevail (Taylor et al., 2007b). This genus is tolerant of moderate organic pollution and also extends into brackish waters. It is abundant on rocks, but is also found on other surfaces such as filamentous algae and macrophytes (Kelly et al., 2001). According to Fore and Grafe (2002), C. placentula prefer alkaline, eutrophic conditions.

The diatom-based water quality improved slightly below the waterfall. The SPI score was 16.4 and although the water quality was still good the diatoms indicate an increased gradient in nutrient *loading downstream of the waterfall as reflected by the increased abundance of Cocconeis species. Nutrient levels were however not problematic as Navicula cymbula was also dominant and generally sensitive to deteriorated water quality and an indicator species of good water quality conditions. The diatoms indicated that water levels fluctuated as sub-aerial species were present. This would have an impact on the life-cycle of aquatic macroinvertebrates.*

According to DWA (2013) the major water quality related impacts were irrigation and forestry along with agriculture. The PES of the SQ reach U20A-04253 was a B/C. Based on available information the diatom-based water quality was determined to be in a B Ecological Category.

15.5.5 Mg_R_EWR4: uMnsunduze River

Only one sample was collected during August 2013. The diatom based water quality was bad with a SPI score of 5. Nutrient levels were elevated and problematic while salinity levels, although elevated at the time of sampling were problematic. Organic pollution levels were unacceptably high and PTVs made up 77.3% of the total count. Dominant species generally have a preference for anthropogenically impacted waters with high organic loads and diatom indicator species for industrial related impact were present at various abundances. Navicula gregaria was dominant and is an indicator species for eutrophic to hyper-eutrophic fresh waters with high electrolyte content, extending into brackish waters (Taylor et al., 2007b).

The diatom community indicated that very heavy pollution levels were present for prolonged periods of time not allowing for system recovery, as a clear cycle of primary and secondary succession was not evident within the community. Pioneer species ('r-strategists') colonise bare surfaces and, over time, increase in quantity (e.g. Eolimna minima). These pioneers are subject to competition from other species (Sellaphora seminulum) until a scouring spate removes most of these, allowing pioneer species to re-establish[1]. Primary succession or the colonization of new or recently disturbed substrates can lead to the death of pioneer species as climax species succeed. Succession also occurs in established communities as a result of changes in the physico-chemical environment (Weitzel, 1979). Therefore E. minima would occur in greater abundance with the onset of organic pollution as this species is a pioneer species while the community would shift to a dominance of S. seminulum as the community adjusts to the organic pollution levels. S. seminulum was outright dominant indicating prolonged exposure to organic pollution input which was most probably originating in the upper reaches of the SQ in the highly urbanized Pietermaritzburg.

Of concern was the occurrence of diatom valve deformities which relates to the presence of metal toxicity. The total abundance of valve deformities was 1% which is regarded as potentially hazardous as the general threshold for valve deformities is usually considered between 1 - 2%. The presence of valve deformities indicated that metal toxicity was present at the time of sampling and could have had an adverse effect on the biological functioning of aquatic biota.

Urbanization was the major impact in SQ U20J-04364 (DWA, 2013) and the PES of the SQ reach was a D/E. During 2010 diatoms were assessed upstream and downstream of the Camps Drift Canal situated in the Duze River in Pietermaritzburg (GroundTruth, 2010) and the results indicated moderate water quality bordering a C to C/D Ecological category. No detailed information was provided other than the SPI score and therefore detailed ecological conditions at the time of

[1] *www.craticula.ncl.ac.uk*

sampling were unavailable. Diatom samples were collected in SQU20J-04459 (downstream of the Rapid EWR site) in the uMnsunduze downstream of the Duzi weir as part of the 2006 eThekwini Municipality - State of Rivers Report (GroundTruth, 2006) and the results indicated poor water quality (SPI score <9). Based on available information the diatom-based water quality was determined to be in a D/E Ecological Category

15.6 REFERENCES

AFNOR. 2000. Norme Française NF T 90–354. Détermination de l'Indice Biologique Diatomées IBD. Association Française de Normalisation, 63 pp.

Battarbee, R.W. 1986. Diatom Analysis. In Berglund BE (ed) Handbook of Holocene Paleoecology and Paleohydrology. John Wiley & Sons Ltd. Chichester. Great Briton. pp 527-570.

Besse A. 2007 Integrated Project to evaluate the Impacts of Global Change on European Freshwater Ecosystems: Task 4 - Generation of an indicator value database for European freshwater species. Euro-limpacs. Project No. GOCE-CT-2003-505540. ALTERRA, Green World Research, Wageningen, Netherlands.

Cattaneo, A., Couillard, Y., Wunsam, S., and Courcelles, M. 2004. Diatom taxonomic and morphological changes as indicators of metal pollution and recovery in Lac Dufault Québec, Canada. Journal of Paleolimnology 32: 163-175.

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

De la Rey, P.A., Taylor, J.C., Laas, A., Van Rensburg, L. & Vosloo, A. 2004. Determining the possible application value of diatoms as indicators of general water quality: A comparison with SASS 5. Water SA 30: 325-332.

Department of Water Affairs (DWA), South Africa, July 2013. Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to Umzimkulu Water Management Area: Status quo assessment, IUA delineation and biophysical node identification. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd.

Dixit, S.S., Smol, J.P., Kingston, J.C. & Charles, D.F. 1992. Diatoms: Powerful indicators of environmental change. Environmental Science and Technology 26: 23–33.

Eloranta, .P and Soininen, J. 2002. Ecological status of Finnish rivers evaluated using benthic diatom communities. J. Appl. Phycol. 14: 1-7.

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

GroundTruth Consultants. 2006. eThekwini Municipality - State of Rivers Report.

GroundTruth Consultants. 2010. Development of Camps Drift Canal: Aquatic Impact Assessment on the uMnsunduze at Camps Drift. Report Reference: GT0261-270111-01.

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

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

Krammer, K. and Lange-Bertalot, H. 1986-1991. Bacillario-phyceae. Süßwasserflora von Mitteleuropa 2 (1-4). Spektrum Akademischer Verlag, Heidelberg. Berlin.

Lavoie I., Campeau S., Grenier M. and Dillon P.J. 2006. A diatom-based index for the biological assessment of eastern Canadian rivers: an application of correspondence analysis (CA). Can. J. Fish. Aquat. Sci. 63(8): 1793–1811.

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

Leira, M. and Sabater, S. 2005. Diatom assemblages distribution in Catalan rivers, NE Spain, in relation to chemical and physiographical factors. Water Research 39: 73-82

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

Schoeman, F.R. 1973. A systematical and ecological study of the diatom flora of Lesotho with special reference to water quality. V&R Printers, Pretoria, South Africa.

Szczepocka, E. 2007. Benthic diatoms from the outlet section of the Bzura River. International Journal of Oceanography and Hydrobiology 36(1): 255-260.

Potapova, M.G. and Ponander, K.C. 2004. Two common North American diatoms, Achnanthidium rivulare sp. nov. and A. deflexum (Reimer) Kingston: Morphology, ecology and comparison with related species. Diatom Research, Volume 19 (1), 33-57.

Potapova, M.G. and Ponander, K.C. 2007. Diatoms from the genus Achnanthidium in flowing waters of the Appalachian Mountains (North America): Ecology, distribution and taxonomic notes. Limnologica 37 227–241.

Taylor, J.C. 2004. The Application of Diatom-Based Pollution Indices in the Vaal Catchment. Unpublished M.Sc. thesis, North-West University, Potchefstroom Campus, Potchefstroom.

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

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

Tilman, D., Kilham, S.S., & Kilham, P. 1982. Phytoplankton community ecology: The role of limiting nutrients. Annual Review of Ecology and Systematics 13: 349–372.

Van Dam, Mertens A and Sinkeldam J (1994) A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Netherlands Journal of Aquatic Ecology 28(1): 177-133.

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

Zelinka M and Marvan P (1961) Zur Prikisierung der biologischen Klassifikation der Reinheit fliessender Gewasser. Archiv. Hydrobiol. 57: 389-407.

16 APPENDIX C: RDRM OUTPUT FILES

A report is generated as part of the RDRM to provide:

- *the hydrology summary;*
- *the parameters that were adjusted from the default;*
- *and the final output results (EWR rules) for all categories.*

This report is provided for all the EWR sites in the following sections.

16.1 Mt_R_EWR1: MTAMVUNA RIVER

16.1.1 Hydrology data summary

Natural Flows:

Area (km^2)	MAR ($m^3 * 10^6$)	Ann.SD ($m^3 * 10^6$)	Q75 ($m^3 * 10^6$)	Ann. CV ($m^3 * 10^6$)
0.0	233.15	107.01	6.53	0.46
% Zero flows	0.0			
Baseflow Parameters:			A	0.95
			B	0.43
BFI				0.45
Hydro Index				4.4

Present Day Flows:

Area (km^2)	MAR ($m^3 * 10^6$)	Ann.SD ($m^3 * 10^6$)	Q75 ($m^3 * 10^6$)	Ann. CV ($m^3 * 10^6$)
0	200.69	100.91	5.24	0.5
% Zero flows	0.0			
Baseflow Parameters:			A	0.95
			B	0.43
BFI				0.43
Hydro Index				4.9

Natural Flows:

MONTH	MEAN ($m^3 * 10^6$)	SD ($m^3 * 10^6$)	CV ($m^3 * 10^6$)
Oct	14.31	15.14	1.06
Nov	24.15	19.57	0.81
Dec	30.49	22.02	0.72
Jan	29.41	20.69	0.7
Feb	28.53	19.7	0.69
Mar	31.53	25.61	0.81
Apr	24.39	21.48	0.88
May	14.73	17.05	1.16
Jun	10.75	14.95	1.39
Jul	8.82	10.44	1.18
Aug	7.54	7.99	1.06
Sep	8.51	15.22	1.79

Present Day Flows:

MONTH	MEAN ($m^3 * 10^6$)	SD ($m^3 * 10^6$)	CV ($m^3 * 10^6$)
Oct	11.9	14.16	1.19
Nov	20.62	18.32	0.89
Dec	26.35	20.39	0.77
Jan	25.27	19.3	0.76
Feb	24.64	18.29	0.74
Mar	27.68	24.33	0.88
Apr	21.41	20.28	0.95
May	12.91	16.24	1.26
Jun	9.36	14.09	1.5
Jul	7.45	9.54	1.28
Aug	6.11	7.13	1.17
Sep	6.99	14.49	2.07

Critical months:	Wet Season	Mar	Dry Season	Sep
Max. baseflows (m^3/s)	6.365		2.767	

16.1.2 Hydraulics data summary

Geomorph. Zone	3
Flood Zone	8
Max. Channel width (m)	45.02
Max. Channel Depth (m)	2.48
Observed Channel XS used	
Observed Rating Curve used	
(Gradients and Roughness n values calibrated)	

Max. Gradient	*0.011*
Min. Gradient	*0.011*
Gradient Shape Factor	*20*
Max. Mannings n	*0.13*
Min. Mannings n	*0.06*
n Shape Factor	*30*

16.1.3 Flow - stressor response data summary

Table of Stress weightings		
Season	**Wet**	**Dry**
Stress at 0 FS:	*9*	*9*
FS Weight:	*1*	*2*
FI Weight:	*2*	*2*
FD Weight:	*2*	*1*
Table of initial SHIFT factors for the Stress Frequency Curves		
Category	**High SHIFT**	**Low SHIFT**
A	*0.1*	*0.025*
A/B	*0.15*	*0.05*
B	*0.2*	*0.075*
B/C	*0.35*	*0.1*
C	*0.4*	*0.125*
C/D	*0.5*	*0.15*
D	*0.6*	*0.175*
Perenniality Rules: All Seasons Perennial Forced		
Alignment of maximum stress to Present Day stress D Category Aligned		
Table of flows (m^3/s) v stress index		
Stress	**Wet Season Flow**	**Dry Season Flow**
0	*6.37*	*2.781*
1	*3.486*	*1.395*
2	*1.772*	*0.616*
3	*1.55*	*0.386*
4	*1.329*	*0.331*
5	*1.107*	*0.276*
6	*0.886*	*0.221*
7	*0.664*	*0.166*
8	*0.443*	*0.11*
9	*0.221*	*0.055*
10	*0*	*0*

16.1.4 High flow estimation summary details

No High flows when natural high flows are < 18% of total flows							
Maximum high flows are 180% greater than normal high flows							
Table of normal high flow requirements (Mill. m^3)							
Category	**A**	**A/B**	**B**	**B/C**	**C**	**C/D**	**D**
Annual	*29.787*	*27.915*	*26.088*	*24.306*	*22.567*	*20.871*	*19.216*
Oct	*3.345*	*3.135*	*2.929*	*2.729*	*2.534*	*2.344*	*2.158*
Nov	*5.336*	*5.001*	*4.674*	*4.354*	*4.043*	*3.739*	*3.442*
Dec	*5.203*	*4.876*	*4.557*	*4.246*	*3.942*	*3.646*	*3.357*
Jan	*5.016*	*4.701*	*4.393*	*4.093*	*3.8*	*3.515*	*3.236*

No High flows when natural high flows are < 18% of total flows							
Maximum high flows are 180% greater than normal high flows							
Table of normal high flow requirements (Mill. m^3)							
Category	**A**	**A/B**	**B**	**B/C**	**C**	**C/D**	**D**
Feb	4.557	4.27	3.991	3.718	3.452	3.193	2.94
Mar	3.912	3.666	3.426	3.192	2.964	2.741	2.524
Apr	2.418	2.266	2.118	1.973	1.832	1.694	1.56
May	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0

16.1.5 Final Reserve summary details

EWR Flows are NOT constrained to be below Natural or Present Day Flows				
Long term mean flow requirements (Mill. m^3 and %MAR)				
Category	**Low Flows**		**Total Flows**	
	Mill. m^3	**%MAR**	**Mill. m^3**	**%MAR**
A	81.358	34.9	120.974	51.9
A/B	71.629	30.7	109.049	46.8
B	60.993	26.2	96.074	41.2
B/C	50.779	21.8	83.463	35.8
C	44.43	19.1	74.775	32.1
C/D	38.209	16.4	66.274	28.4
D	33.129	14.2	58.969	25.3

16.1.6 Flow duration and Reserve assurance tables

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Natural Total flow duration curve (mill. m^3)										
Oct	25.205	18.62	14.505	10.99	9.54	8.79	7.82	6.39	5	2.695
Nov	49.6	33.35	24.545	22.34	17.495	15.14	12.885	10.34	9.205	5.202
Dec	67.61	52.24	37.935	29.35	23.6	19.15	15.09	12.07	8.835	5.282
Jan	55.215	43.87	34.535	29.22	25.53	21.38	17.005	12.9	8.63	5.897
Feb	60.08	39.15	31.085	26.35	24.02	20.15	16.94	13.93	10.845	6.165
Mar	65.505	42.69	32.565	27.73	23.425	20.51	17.81	15.08	10.635	7.378
Apr	50.06	33.13	25.44	21.12	18.27	14.45	11.615	10.25	8.55	4.018
May	27.03	17.74	14.44	12.17	10.555	9.12	7.01	6.37	5.27	4.179
Jun	21.695	13.48	8.875	7.53	6.575	5.51	4.495	3.68	3.285	2.513
Jul	22.24	12.54	7.51	6.63	4.96	4.27	3.36	2.72	2.38	1.825
Aug	17.785	10.15	7.12	5.53	4.54	3.96	3.415	2.86	2.365	1.894
Sep	15.54	10.67	7.69	6.3	5.395	4.47	3.965	3.39	2.475	1.557
Natural Baseflow flow duration curve (mill. m^3)										
Oct	9.939	8.238	6.726	5.837	4.922	4.546	4.046	3.688	3.157	2.262
Nov	14.289	10.603	9.019	7.871	6.567	6.057	5.525	4.906	3.972	3.015
Dec	16.557	13.574	11.388	10.284	9.024	7.506	6.815	5.927	4.274	3.342
Jan	16.71	14.677	13.414	11.611	10.093	8.798	7.902	6.642	4.924	3.581
Feb	18.623	15.815	12.868	11.9	10.242	9.254	8.321	7.217	5.946	4.371
Mar	19.423	16.746	14.222	12.194	10.939	10.073	9.26	8.299	7.316	4.655

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Apr	18.509	15.663	14.134	11.718	10.565	9.601	8.815	7.71	6.712	4.018
May	17.103	13.47	10.493	9.34	8.701	7.527	6.65	6.254	5.065	4.174
Jun	14.415	9.372	8.226	6.92	6.235	5.32	4.45	3.68	3.285	2.513
Jul	10.8	8.06	6.864	5.55	4.72	3.97	3.294	2.718	2.38	1.825
Aug	9.36	7.775	5.89	4.64	3.96	3.5	3.045	2.607	2.176	1.855
Sep	8.504	7.01	5.323	4.321	3.934	3.447	3.175	2.871	2.29	1.557
Category Low Flow Assurance curves (mill. m^3)										
A Category										
Oct	7.39	7.279	6.634	5.763	4.945	4.239	3.282	2.244	1.908	1.689
Nov	10.326	9.396	8.473	7.519	6.333	5.453	4.316	2.99	2.598	2.589
Dec	12.703	11.931	11.358	10.313	8.997	7.12	5.585	3.942	2.927	2.919
Jan	12.936	12.822	12.818	11.623	9.97	8.249	6.406	4.49	3.168	3.148
Feb	12.83	12.41	11.344	10.673	9.268	7.808	6.307	4.647	3.485	3.388
Mar	14.834	14.493	13.87	12.194	10.939	9.291	7.795	6.144	4.713	4.527
Apr	14.612	13.247	13.14	11.434	10.207	8.78	7.108	5.343	4.143	2.962
May	13.246	11.571	10.469	9.442	8.542	7.118	5.461	4.182	3.584	3.206
Jun	10.34	8.117	7.76	6.18	5.35	4.45	3.507	2.268	2.002	1.703
Jul	8.202	7.19	6.115	5.39	3.95	3.48	2.657	1.798	1.545	1.092
Aug	7.71	6.733	5.565	4.27	3.305	2.92	2.355	1.75	1.5	1.091
Sep	6.14	5.945	5.151	4.181	3.807	3.25	2.442	1.581	1.316	0.789
A/B Category										
Oct	6.314	6.209	5.857	5.461	4.39	3.567	2.633	1.919	1.698	1.555
Nov	8.897	8.064	7.437	7.016	5.598	4.637	3.543	2.553	2.421	2.42
Dec	11.002	10.294	9.93	9.427	7.899	6.118	4.679	3.361	2.742	2.739
Jan	11.257	11.257	11.257	10.517	8.729	7.149	5.444	3.827	2.972	2.971
Feb	11.143	10.755	9.948	9.639	8.111	6.788	5.41	3.962	3.259	3.235
Mar	12.911	12.577	11.969	10.969	9.477	8.225	6.764	5.151	4.59	4.419
Apr	12.647	11.542	11.536	10.35	8.927	7.657	6.133	4.553	3.905	2.962
May	11.456	9.976	9.165	8.693	7.51	6.117	4.562	3.566	3.413	3.206
Jun	8.916	6.943	6.853	6.18	5.296	4.127	2.833	1.94	1.839	1.703
Jul	7.032	6.132	5.987	5.39	3.95	3.229	2.114	1.52	1.397	1.092
Aug	6.603	5.734	5.146	4.27	3.305	2.77	2.066	1.493	1.423	1.091
Sep	5.239	5.041	4.68	4.089	3.385	2.716	1.896	1.416	1.147	0.789
B Category										
Oct	5.233	5.118	4.76	4.504	3.723	2.912	2.124	1.702	1.553	1.5
Nov	7.465	6.711	6.107	5.818	4.781	3.855	2.906	2.342	2.339	2.336
Dec	9.3	8.64	8.258	7.876	6.815	5.182	3.894	2.976	2.647	2.646
Jan	9.456	9.428	9.427	8.823	7.568	6.14	4.572	3.391	2.875	2.874
Feb	9.455	9.089	8.318	8.091	7.039	5.857	4.578	3.519	3.143	3.136
Mar	10.987	10.661	10.068	9.191	8.325	7.159	5.733	4.67	4.467	4.3
Apr	10.682	9.698	9.615	8.668	7.761	6.642	5.215	4.058	3.761	2.962
May	9.665	8.361	7.588	7.246	6.47	5.181	3.789	3.31	3.308	3.206
Jun	7.491	5.747	5.606	5.257	4.523	3.405	2.298	1.769	1.769	1.703
Jul	5.859	5.052	4.865	4.517	3.536	2.624	1.689	1.352	1.341	1.092
Aug	5.495	4.717	4.174	3.645	2.939	2.296	1.707	1.365	1.365	1.091
Sep	4.338	4.137	3.771	3.365	2.861	2.182	1.523	1.251	0.996	0.789
B/C Category										
Oct	4.254	4.183	3.945	3.678	2.832	2.081	1.702	1.408	1.407	1.369

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Nov	*6.141*	*5.536*	*5.094*	*4.824*	*3.731*	*2.843*	*2.334*	*2.136*	*2.135*	*2.134*
Dec	*7.696*	*7.183*	*6.951*	*6.659*	*5.525*	*3.948*	*3.133*	*2.626*	*2.43*	*2.427*
Jan	*8.027*	*8.027*	*8.027*	*7.532*	*6.224*	*4.786*	*3.686*	*3.053*	*2.651*	*2.645*
Feb	*7.859*	*7.604*	*7.101*	*6.918*	*5.813*	*4.594*	*3.69*	*3.236*	*2.919*	*2.911*
Mar	*9.152*	*8.938*	*8.547*	*7.904*	*6.945*	*5.652*	*4.659*	*4.434*	*4.208*	*4.023*
Apr	*8.828*	*8.131*	*8.122*	*7.392*	*6.437*	*5.249*	*4.203*	*3.782*	*3.521*	*2.962*
May	*7.973*	*6.943*	*6.368*	*6.085*	*5.209*	*3.95*	*3.075*	*3.065*	*3.063*	*3.037*
Jun	*6.154*	*4.718*	*4.669*	*4.333*	*3.511*	*2.479*	*1.839*	*1.606*	*1.603*	*1.584*
Jul	*4.765*	*4.128*	*4.045*	*3.691*	*2.68*	*1.858*	*1.357*	*1.203*	*1.202*	*1.092*
Aug	*4.461*	*3.847*	*3.45*	*2.961*	*2.264*	*1.695*	*1.373*	*1.229*	*1.227*	*1.091*
Sep	*3.499*	*3.365*	*3.123*	*2.724*	*2.13*	*1.517*	*1.228*	*0.979*	*0.901*	*0.788*
C Category										
Oct	*3.642*	*3.565*	*3.31*	*3.014*	*2.249*	*1.835*	*1.528*	*1.346*	*1.346*	*1.315*
Nov	*5.312*	*4.757*	*4.32*	*4.014*	*3.017*	*2.48*	*2.147*	*2.055*	*2.053*	*2.051*
Dec	*6.698*	*6.217*	*5.966*	*5.644*	*4.587*	*3.402*	*2.941*	*2.533*	*2.34*	*2.336*
Jan	*6.924*	*6.924*	*6.924*	*6.443*	*5.213*	*4.086*	*3.507*	*2.951*	*2.555*	*2.549*
Feb	*6.861*	*6.618*	*6.112*	*5.926*	*4.882*	*3.92*	*3.539*	*3.134*	*2.823*	*2.815*
Mar	*8.008*	*7.799*	*7.416*	*6.788*	*5.85*	*4.725*	*4.526*	*4.305*	*4.085*	*3.904*
Apr	*7.679*	*7.056*	*6.996*	*6.312*	*5.416*	*4.467*	*4.051*	*3.669*	*3.412*	*2.962*
May	*6.928*	*6.002*	*5.443*	*5.125*	*4.302*	*3.399*	*2.968*	*2.964*	*2.961*	*2.949*
Jun	*5.329*	*4.035*	*3.944*	*3.584*	*2.829*	*2.169*	*1.664*	*1.539*	*1.536*	*1.526*
Jul	*4.098*	*3.516*	*3.388*	*3.027*	*2.121*	*1.642*	*1.202*	*1.152*	*1.149*	*1.092*
Aug	*3.832*	*3.273*	*2.892*	*2.411*	*1.811*	*1.48*	*1.278*	*1.169*	*1.168*	*1.091*
Sep	*2.992*	*2.857*	*2.611*	*2.208*	*1.617*	*1.36*	*1.067*	*0.939*	*0.861*	*0.752*
C/D Category										
Oct	*3.017*	*2.925*	*2.638*	*2.325*	*1.889*	*1.6*	*1.375*	*1.245*	*1.245*	*1.223*
Nov	*4.47*	*3.955*	*3.504*	*3.168*	*2.518*	*2.218*	*1.976*	*1.913*	*1.911*	*1.909*
Dec	*5.688*	*5.225*	*4.932*	*4.571*	*3.789*	*3.11*	*2.754*	*2.405*	*2.187*	*2.181*
Jan	*5.792*	*5.771*	*5.771*	*5.291*	*4.295*	*3.8*	*3.319*	*2.809*	*2.387*	*2.386*
Feb	*5.852*	*5.61*	*5.069*	*4.873*	*4.021*	*3.666*	*3.376*	*2.991*	*2.664*	*2.655*
Mar	*6.853*	*6.636*	*6.239*	*5.586*	*4.729*	*4.559*	*4.352*	*4.123*	*3.894*	*3.706*
Apr	*6.516*	*5.976*	*5.816*	*5.164*	*4.46*	*4.202*	*3.881*	*3.503*	*3.242*	*2.878*
May	*5.871*	*5.036*	*4.471*	*4.114*	*3.561*	*3.109*	*2.794*	*2.79*	*2.786*	*2.783*
Jun	*4.492*	*3.332*	*3.18*	*2.804*	*2.362*	*1.918*	*1.508*	*1.415*	*1.414*	*1.414*
Jul	*3.421*	*2.884*	*2.703*	*2.338*	*1.783*	*1.419*	*1.069*	*1.05*	*1.049*	*1.039*
Aug	*3.193*	*2.678*	*2.299*	*1.836*	*1.523*	*1.312*	*1.187*	*1.069*	*1.069*	*1.065*
Sep	*2.478*	*2.332*	*2.066*	*1.63*	*1.414*	*1.156*	*0.963*	*0.878*	*0.793*	*0.69*
D Category										
Oct	*2.397*	*2.292*	*2.064*	*1.986*	*1.67*	*1.412*	*1.301*	*1.163*	*1.144*	*1.118*
Nov	*3.628*	*3.159*	*2.761*	*2.69*	*2.275*	*2.018*	*1.879*	*1.769*	*1.768*	*1.766*
Dec	*4.678*	*4.238*	*3.956*	*3.862*	*3.523*	*2.901*	*2.629*	*2.277*	*2.027*	*2.025*
Jan	*4.754*	*4.69*	*4.685*	*4.452*	*4.039*	*3.608*	*3.176*	*2.667*	*2.227*	*2.223*
Feb	*4.843*	*4.604*	*4.132*	*4.102*	*3.792*	*3.498*	*3.235*	*2.848*	*2.507*	*2.494*
Mar	*5.699*	*5.473*	*5.061*	*4.699*	*4.569*	*4.393*	*4.178*	*3.941*	*3.704*	*3.509*
Apr	*5.354*	*4.901*	*4.709*	*4.353*	*4.221*	*4.032*	*3.722*	*3.339*	*3.071*	*2.706*
May	*4.814*	*4.075*	*3.566*	*3.484*	*3.298*	*2.901*	*2.616*	*2.613*	*2.61*	*2.608*
Jun	*3.657*	*2.633*	*2.5*	*2.388*	*2.124*	*1.722*	*1.429*	*1.299*	*1.297*	*1.295*
Jul	*2.744*	*2.257*	*2.13*	*1.992*	*1.571*	*1.241*	*1.009*	*0.978*	*0.953*	*0.951*

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Aug	*2.555*	*2.089*	*1.775*	*1.575*	*1.359*	*1.19*	*1.131*	*1.001*	*0.97*	*0.97*
Sep	*1.963*	*1.806*	*1.573*	*1.435*	*1.23*	*0.99*	*0.908*	*0.817*	*0.725*	*0.628*
Category Total Flow Assurance curves (mill. m^3)										
A Category										
Oct	*18.935*	*15.39*	*11.4*	*8.66*	*7.39*	*6.89*	*5.784*	*3.708*	*1.954*	*1.689*
Nov	*28.745*	*22.691*	*17.784*	*14.053*	*11.694*	*10.456*	*8.309*	*5.324*	*2.671*	*2.589*
Dec	*30.663*	*24.895*	*20.437*	*16.684*	*14.225*	*11.998*	*9.478*	*6.219*	*2.998*	*2.919*
Jan	*30.249*	*25.319*	*21.57*	*17.765*	*15.01*	*12.951*	*10.159*	*6.685*	*3.237*	*3.148*
Feb	*28.558*	*23.763*	*19.295*	*16.253*	*13.846*	*12.08*	*9.716*	*6.64*	*3.548*	*3.388*
Mar	*28.336*	*24.239*	*20.696*	*16.984*	*14.869*	*12.958*	*10.722*	*7.855*	*4.767*	*4.527*
Apr	*22.958*	*19.272*	*17.36*	*14.395*	*12.637*	*11.047*	*8.917*	*6.401*	*4.176*	*2.962*
May	*13.246*	*11.571*	*10.469*	*9.442*	*8.542*	*7.118*	*5.461*	*4.182*	*3.584*	*3.206*
Jun	*10.34*	*8.117*	*7.76*	*6.18*	*5.35*	*4.45*	*3.507*	*2.268*	*2.002*	*1.703*
Jul	*8.202*	*7.19*	*6.115*	*5.39*	*3.95*	*3.48*	*2.657*	*1.798*	*1.545*	*1.092*
Aug	*7.71*	*6.733*	*5.565*	*4.27*	*3.305*	*2.92*	*2.355*	*1.75*	*1.5*	*1.091*
Sep	*6.14*	*5.945*	*5.151*	*4.181*	*3.807*	*3.25*	*2.442*	*1.581*	*1.316*	*0.789*
A/B Category										
Oct	*17.133*	*14.019*	*11.326*	*8.66*	*7.39*	*6.506*	*4.978*	*3.29*	*1.741*	*1.555*
Nov	*26.159*	*20.524*	*16.164*	*13.139*	*10.623*	*9.326*	*7.284*	*4.741*	*2.49*	*2.42*
Dec	*27.834*	*22.444*	*18.439*	*15.398*	*12.798*	*10.69*	*8.327*	*5.494*	*2.809*	*2.739*
Jan	*27.482*	*22.969*	*19.459*	*16.273*	*13.453*	*11.556*	*8.961*	*5.883*	*3.037*	*2.971*
Feb	*25.883*	*21.395*	*17.399*	*14.868*	*12.401*	*10.792*	*8.605*	*5.83*	*3.318*	*3.235*
Mar	*25.564*	*21.711*	*18.365*	*15.458*	*13.16*	*11.662*	*9.507*	*6.755*	*4.64*	*4.419*
Apr	*20.469*	*17.189*	*15.49*	*13.125*	*11.204*	*9.782*	*7.828*	*5.545*	*3.936*	*2.962*
May	*11.456*	*9.976*	*9.165*	*8.693*	*7.51*	*6.117*	*4.562*	*3.566*	*3.413*	*3.206*
Jun	*8.916*	*6.943*	*6.853*	*6.18*	*5.296*	*4.127*	*2.833*	*1.94*	*1.839*	*1.703*
Jul	*7.032*	*6.132*	*5.987*	*5.39*	*3.95*	*3.229*	*2.114*	*1.52*	*1.397*	*1.092*
Aug	*6.603*	*5.734*	*5.146*	*4.27*	*3.305*	*2.77*	*2.066*	*1.493*	*1.423*	*1.091*
Sep	*5.239*	*5.041*	*4.68*	*4.089*	*3.385*	*2.716*	*1.896*	*1.416*	*1.147*	*0.789*
B Category										
Oct	*15.344*	*12.416*	*9.871*	*8.091*	*6.666*	*5.658*	*4.316*	*2.984*	*1.594*	*1.5*
Nov	*23.596*	*18.355*	*14.262*	*11.541*	*9.476*	*8.237*	*6.403*	*4.386*	*2.403*	*2.336*
Dec	*25.03*	*19.994*	*16.21*	*13.457*	*11.394*	*9.454*	*7.303*	*4.97*	*2.71*	*2.646*
Jan	*24.619*	*20.373*	*17.093*	*14.203*	*11.982*	*10.259*	*7.859*	*5.313*	*2.935*	*2.874*
Feb	*23.231*	*19.032*	*15.282*	*12.978*	*11.049*	*9.599*	*7.564*	*5.265*	*3.198*	*3.136*
Mar	*22.812*	*19.197*	*16.046*	*13.387*	*11.768*	*10.37*	*8.296*	*6.169*	*4.514*	*4.3*
Apr	*17.992*	*14.975*	*13.31*	*11.262*	*9.889*	*8.627*	*6.799*	*4.985*	*3.79*	*2.962*
May	*9.665*	*8.361*	*7.588*	*7.246*	*6.47*	*5.181*	*3.789*	*3.31*	*3.308*	*3.206*
Jun	*7.491*	*5.747*	*5.606*	*5.257*	*4.523*	*3.405*	*2.298*	*1.769*	*1.769*	*1.703*
Jul	*5.859*	*5.052*	*4.865*	*4.517*	*3.536*	*2.624*	*1.689*	*1.352*	*1.341*	*1.092*
Aug	*5.495*	*4.717*	*4.174*	*3.645*	*2.939*	*2.296*	*1.707*	*1.365*	*1.365*	*1.091*
Sep	*4.338*	*4.137*	*3.771*	*3.365*	*2.861*	*2.182*	*1.523*	*1.251*	*0.996*	*0.789*
B/C Category										
Oct	*13.674*	*10.983*	*8.707*	*7.02*	*5.574*	*4.639*	*3.743*	*2.602*	*1.445*	*1.369*
Nov	*21.17*	*16.384*	*12.692*	*10.156*	*8.106*	*6.926*	*5.592*	*4.041*	*2.195*	*2.134*
Dec	*22.351*	*17.762*	*14.36*	*11.858*	*9.792*	*7.929*	*6.309*	*4.484*	*2.488*	*2.427*
Jan	*22.155*	*18.225*	*15.169*	*12.544*	*10.337*	*8.623*	*6.748*	*4.844*	*2.707*	*2.645*
Feb	*20.693*	*16.868*	*13.589*	*11.471*	*9.549*	*8.08*	*6.472*	*4.863*	*2.97*	*2.911*

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Mar	*20.17*	*16.891*	*14.116*	*11.813*	*10.152*	*8.645*	*7.047*	*5.83*	*4.252*	*4.023*
Apr	*15.639*	*13.047*	*11.565*	*9.809*	*8.419*	*7.099*	*5.679*	*4.646*	*3.549*	*2.962*
May	*7.973*	*6.943*	*6.368*	*6.085*	*5.209*	*3.95*	*3.075*	*3.065*	*3.063*	*3.037*
Jun	*6.154*	*4.718*	*4.669*	*4.333*	*3.511*	*2.479*	*1.839*	*1.606*	*1.603*	*1.584*
Jul	*4.765*	*4.128*	*4.045*	*3.691*	*2.68*	*1.858*	*1.357*	*1.203*	*1.202*	*1.092*
Aug	*4.461*	*3.847*	*3.45*	*2.961*	*2.264*	*1.695*	*1.373*	*1.229*	*1.227*	*1.091*
Sep	*3.499*	*3.365*	*3.123*	*2.724*	*2.13*	*1.517*	*1.228*	*0.979*	*0.901*	*0.788*
C Category										
Oct	*12.389*	*9.878*	*7.732*	*6.117*	*4.795*	*4.211*	*3.424*	*2.455*	*1.381*	*1.315*
Nov	*19.266*	*14.829*	*11.375*	*8.965*	*7.079*	*6.27*	*5.172*	*3.824*	*2.109*	*2.051*
Dec	*20.305*	*16.039*	*12.845*	*10.471*	*8.548*	*7.098*	*5.89*	*4.257*	*2.394*	*2.336*
Jan	*20.041*	*16.392*	*13.555*	*11.097*	*9.031*	*7.648*	*6.35*	*4.613*	*2.608*	*2.549*
Feb	*18.777*	*15.219*	*12.136*	*10.154*	*8.35*	*7.156*	*6.122*	*4.644*	*2.871*	*2.815*
Mar	*18.238*	*15.182*	*12.588*	*10.417*	*8.828*	*7.504*	*6.743*	*5.602*	*4.126*	*3.904*
Apr	*14.003*	*11.62*	*10.193*	*8.556*	*7.257*	*6.185*	*5.422*	*4.47*	*3.438*	*2.962*
May	*6.928*	*6.002*	*5.443*	*5.125*	*4.302*	*3.399*	*2.968*	*2.964*	*2.961*	*2.949*
Jun	*5.329*	*4.035*	*3.944*	*3.584*	*2.829*	*2.169*	*1.664*	*1.539*	*1.536*	*1.526*
Jul	*4.098*	*3.516*	*3.388*	*3.027*	*2.121*	*1.642*	*1.202*	*1.152*	*1.149*	*1.092*
Aug	*3.832*	*3.273*	*2.892*	*2.411*	*1.811*	*1.48*	*1.278*	*1.169*	*1.168*	*1.091*
Sep	*2.992*	*2.857*	*2.611*	*2.208*	*1.617*	*1.36*	*1.067*	*0.939*	*0.861*	*0.752*
C/D Category										
Oct	*11.106*	*8.764*	*6.727*	*5.195*	*4.243*	*3.797*	*3.129*	*2.271*	*1.277*	*1.223*
Nov	*17.375*	*13.27*	*10.028*	*7.747*	*6.275*	*5.723*	*4.773*	*3.549*	*1.962*	*1.909*
Dec	*18.272*	*14.309*	*11.294*	*9.036*	*7.452*	*6.528*	*5.482*	*4*	*2.237*	*2.181*
Jan	*17.923*	*14.528*	*11.903*	*9.594*	*7.826*	*7.095*	*5.949*	*4.346*	*2.436*	*2.386*
Feb	*16.872*	*13.564*	*10.64*	*8.783*	*7.228*	*6.659*	*5.765*	*4.388*	*2.708*	*2.655*
Mar	*16.314*	*13.464*	*11.021*	*8.942*	*7.482*	*7.128*	*6.402*	*5.322*	*3.932*	*3.706*
Apr	*12.364*	*10.197*	*8.773*	*7.239*	*6.162*	*5.791*	*5.149*	*4.245*	*3.265*	*2.878*
May	*5.871*	*5.036*	*4.471*	*4.114*	*3.561*	*3.109*	*2.794*	*2.79*	*2.786*	*2.783*
Jun	*4.492*	*3.332*	*3.18*	*2.804*	*2.362*	*1.918*	*1.508*	*1.415*	*1.414*	*1.414*
Jul	*3.421*	*2.884*	*2.703*	*2.338*	*1.783*	*1.419*	*1.069*	*1.05*	*1.049*	*1.039*
Aug	*3.193*	*2.678*	*2.299*	*1.836*	*1.523*	*1.312*	*1.187*	*1.069*	*1.069*	*1.065*
Sep	*2.478*	*2.332*	*2.066*	*1.63*	*1.414*	*1.156*	*0.963*	*0.878*	*0.793*	*0.69*
D Category										
Oct	*9.845*	*7.668*	*5.83*	*4.629*	*3.838*	*3.435*	*2.916*	*2.107*	*1.174*	*1.118*
Nov	*15.51*	*11.736*	*8.767*	*6.905*	*5.734*	*5.245*	*4.454*	*3.275*	*1.815*	*1.766*
Dec	*16.264*	*12.601*	*9.814*	*7.973*	*6.896*	*6.048*	*5.14*	*3.746*	*2.073*	*2.025*
Jan	*15.923*	*12.752*	*10.332*	*8.414*	*7.29*	*6.642*	*5.597*	*4.082*	*2.271*	*2.223*
Feb	*14.989*	*11.928*	*9.261*	*7.702*	*6.745*	*6.254*	*5.434*	*4.134*	*2.548*	*2.494*
Mar	*14.409*	*11.76*	*9.464*	*7.789*	*7.104*	*6.759*	*6.066*	*5.045*	*3.738*	*3.509*
Apr	*10.738*	*8.788*	*7.431*	*6.263*	*5.789*	*5.495*	*4.889*	*4.022*	*3.093*	*2.706*
May	*4.814*	*4.075*	*3.566*	*3.484*	*3.298*	*2.901*	*2.616*	*2.613*	*2.61*	*2.608*
Jun	*3.657*	*2.633*	*2.5*	*2.388*	*2.124*	*1.722*	*1.429*	*1.299*	*1.297*	*1.295*
Jul	*2.744*	*2.257*	*2.13*	*1.992*	*1.571*	*1.241*	*1.009*	*0.978*	*0.953*	*0.951*
Aug	*2.555*	*2.089*	*1.775*	*1.575*	*1.359*	*1.19*	*1.131*	*1.001*	*0.97*	*0.97*
Sep	*1.963*	*1.806*	*1.573*	*1.435*	*1.23*	*0.99*	*0.908*	*0.817*	*0.725*	*0.628*

16.2 LO_R_EWR1: LOVU RIVER

16.2.1 Hydrology data summary

Natural Flows:					Present Day Flows:				
Area (km^2)	**MAR**	**Ann.SD**	**Q75**	**Ann. CV**	**Area (km^2)**	**MAR**	**Ann.SD**	**Q75**	**Ann. CV**
	($m^3 * 10^6$)					**($m^3 * 10^6$)**			
0.0	87.76	64.02	2.4	0.73	0	73.42	60.11	1.7	0.82
% Zero flows	0.0				% Zero flows	0.0			
Baseflow Parameters:			A	0.95	Baseflow Parameters:			A	0.95
			B	0.43				B	0.43
BFI				0.47	BFI				0.42
Hydro Index				5.3	Hydro Index				6.6

MONTH	**MEAN**	**SD**	**CV**	**MONTH**	**MEAN**	**SD**	**CV**
	($m^3 * 10^6$)				**($m^3 * 10^6$)**		
Oct	4.7	8.73	1.86	Oct	4.04	7.95	1.97
Nov	7.77	12.74	1.64	Nov	7.07	11.89	1.68
Dec	10.07	15.21	1.51	Dec	8.54	13.52	1.58
Jan	10.18	12.04	1.18	Jan	8.89	11.59	1.3
Feb	10.95	10.76	0.98	Feb	9.31	10.05	1.08
Mar	14.14	25.26	1.79	Mar	11.94	23.3	1.95
Apr	9.48	11.93	1.26	Apr	7.71	10.84	1.41
May	5.62	5.79	1.03	May	4.26	4.85	1.14
Jun	4.45	7.58	1.7	Jun	3.4	6.6	1.94
Jul	3.11	3.5	1.13	Jul	2.39	3.21	1.34
Aug	2.56	1.73	0.68	Aug	1.92	1.62	0.84
Sep	4.73	20.38	4.3	Sep	3.96	19.3	4.88

Critical months:	Wet Season	Mar	Dry Season	Sep
Max. baseflows (m^3/s)	2.366		1.127	

16.2.2 Hydraulics data summary

Geomorph. Zone	3
Flood Zone	8
Max. Channel width (m)	39.17
Max. Channel Depth (m)	2.46
Observed Channel XS used	
Observed Rating Curve used	
(Gradients and Roughness n values calibrated)	
Max. Gradient	0.007
Min. Gradient	0.0052
Gradient Shape Factor	20
Max. Mannings n	0.12
Min. Mannings n	0.043
n Shape Factor	32

16.2.3 Flow - stressor response data summary

Table of initial SHIFT factors for the Stress Frequency Curves		
Category	**High SHIFT**	**Low SHIFT**
A	0.05	0.025
A/B	0.1	0.075
B	0.2	0.1
B/C	0.4	0.2
C	0.5	0.25
C/D	0.6	0.3
D	0.7	0.35
Perenniality Rules: All Seasons Perennial Forced		
Alignment of maximum stress to Present Day stress B/C Category Aligned		
Table of flows (m^3/s) v stress index		
Stress	**Wet Season Flow**	**Dry Season Flow**
0	2.384	1.146
1	2.168	0.91
2	1.645	0.744
3	0.783	0.674
4	0.523	0.163
5	0.325	0.136
6	0.26	0.109
7	0.195	0.081
8	0.13	0.054
9	0.065	0.027
10	0	0

16.2.4 High flow estimation summary details

No High flows when natural high flows are < 20% of total flows							
Maximum high flows are 400% greater than normal high flows							
Table of normal high flow requirements (Mill. m^3)							
Category	**A**	**A/B**	**B**	**B/C**	**C**	**C/D**	**D**
Annual	13.828	12.809	11.832	10.896	9.999	9.141	8.318
Oct	0.902	0.836	0.772	0.711	0.652	0.596	0.543
Nov	1.788	1.657	1.53	1.409	1.293	1.182	1.076
Dec	1.746	1.617	1.494	1.376	1.263	1.154	1.05
Jan	2.284	2.116	1.955	1.8	1.652	1.51	1.374
Feb	3.078	2.852	2.634	2.426	2.226	2.035	1.852
Mar	2.217	2.054	1.897	1.747	1.603	1.466	1.334
Apr	1.41	1.306	1.207	1.111	1.02	0.932	0.848
May	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0
Sep	0.401	0.372	0.343	0.316	0.29	0.265	0.241

16.2.5 Final Reserve summary details

EWR Flows are constrained to be below Natural or Present Day Flows				
Long term mean flow requirements (Mill. m^3 and %MAR)				
Category	**Low Flows**		**Total Flows**	
	Mill. m^3	**%MAR**	**Mill. m^3**	**%MAR**
A	30.712	35	46.052	52.5
A/B	29.053	33.1	43.9	50
B	27.394	31.2	41.462	47.2
B/C	20.044	22.8	33.231	37.9
C	16.034	18.3	28.136	32.1
C/D	12.402	14.1	23.465	26.7
D	9.624	11	19.691	22.4

16.2.6 Flow duration and Reserve assurance tables

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Natural Total flow duration curve (mill. m^3)										
Oct	7.13	4.58	3.45	3.1	2.8	2.54	2.295	1.88	1.565	0.951
Nov	17.735	8.15	5.665	4.76	3.965	3.42	2.795	2.46	2.145	1.466
Dec	21.55	13.76	8.395	6.58	4.74	4.05	3.435	2.9	2.44	1.462
Jan	24.255	13.65	9.575	7.55	6.18	5.69	4.81	3.8	2.845	1.484
Feb	24.47	14.4	10.29	8.58	7.435	6.47	5.41	4.2	3.205	1.95
Mar	24.52	14.81	11.195	9.19	7.83	6.47	5.715	4.56	3.45	2.133
Apr	19.26	10.88	7.705	6.46	6.12	5.15	4.62	3.91	2.9	1.86
May	7.86	6.2	5.4	4.65	4.31	4.02	3.525	2.85	2.24	1.405
Jun	5.79	4.51	3.89	3.35	3.01	2.69	2.505	2.16	1.64	0.891
Jul	4.825	3.55	2.91	2.7	2.375	2.06	1.865	1.61	1.315	0.753
Aug	4.84	3.45	2.72	2.29	2.055	1.86	1.62	1.41	1.175	0.66
Sep	4.645	3.54	2.875	2.46	2.19	1.82	1.665	1.48	1.08	0.577
Natural Baseflow flow duration curve (mill. m^3)										
Oct	3.714	2.907	2.609	2.189	1.949	1.69	1.583	1.419	1.233	0.758
Nov	5.138	3.401	2.862	2.588	2.281	2.099	1.784	1.612	1.337	0.975
Dec	7.225	4.437	3.539	3.078	2.721	2.314	2.045	1.813	1.55	1.111
Jan	7.229	5.634	4.348	3.466	3.211	2.732	2.513	2.101	1.836	1.241
Feb	7.259	5.734	4.868	4.223	3.304	3.09	2.828	2.401	2.096	1.288
Mar	8.025	6.073	5.329	4.67	4.115	3.501	3.179	2.665	2.185	1.318
Apr	7.644	6.07	5.01	4.36	3.797	3.493	3.064	2.631	2.028	1.37
May	6.387	4.961	4.185	3.982	3.491	3.202	2.797	2.553	1.926	1.214
Jun	4.99	3.957	3.549	3.122	2.766	2.588	2.405	2.027	1.64	0.883
Jul	4.439	3.06	2.75	2.552	2.29	2.037	1.808	1.61	1.315	0.753
Aug	4.025	2.882	2.4	2.17	1.945	1.81	1.54	1.35	1.175	0.66
Sep	3.655	2.813	2.391	2.077	1.775	1.67	1.489	1.33	1.05	0.575
Category Low Flow Assurance curves (mill. m^3)										
A Category										
Oct	2.854	2.624	2.51	2.253	1.963	1.717	1.544	1.206	0.891	0.434
Nov	4.155	3.049	2.741	2.495	2.207	2.011	1.666	1.282	0.942	0.727
Dec	5.522	4.398	3.437	3.077	2.701	2.327	1.905	1.437	1.092	0.76

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Jan	5.475	5.211	4.308	3.506	3.142	2.71	2.207	1.613	1.261	0.611
Feb	5.145	5.038	4.419	3.761	3.04	2.737	2.179	1.576	1.288	0.868
Mar	6.177	6.073	5.329	4.67	4.115	3.501	2.512	1.832	1.49	1.058
Apr	5.813	5.512	4.732	4.158	3.699	3.299	2.459	1.792	1.362	0.75
May	4.891	4.6	4.156	3.82	3.18	2.88	2.355	1.76	1.28	0.291
Jun	3.776	3.41	3.01	2.47	2.195	1.91	1.615	1.17	0.8	0.186
Jul	3.331	2.84	2.17	1.8	1.67	1.31	1.115	0.89	0.66	0.2
Aug	3.049	2.651	2.22	1.82	1.5	1.17	0.965	0.73	0.54	0.19
Sep	2.683	2.478	2.252	1.94	1.718	1.32	1.13	0.89	0.68	0.342
A/B Category										
Oct	2.579	2.402	2.331	2.138	1.96	1.692	1.336	0.923	0.651	0.434
Nov	3.83	2.8	2.568	2.384	2.201	1.947	1.431	1.005	0.71	0.628
Dec	5.209	4.132	3.276	2.973	2.692	2.227	1.621	1.157	0.861	0.76
Jan	5.161	4.969	4.203	3.419	3.127	2.538	1.845	1.363	1.063	0.611
Feb	4.868	4.868	4.373	3.723	3.02	2.518	1.797	1.391	1.131	0.868
Mar	5.894	5.809	5.329	4.67	4.115	3.13	2.037	1.683	1.379	1.058
Apr	5.464	5.282	4.681	4.121	3.671	2.994	2.007	1.607	1.21	0.75
May	4.558	4.349	4.037	3.82	3.18	2.88	2.005	1.603	1.141	0.291
Jun	3.446	3.335	3.01	2.47	2.195	1.91	1.615	1.17	0.8	0.186
Jul	3.005	2.591	2.17	1.8	1.67	1.31	1.115	0.89	0.66	0.2
Aug	2.737	2.422	2.215	1.82	1.5	1.17	0.965	0.73	0.54	0.19
Sep	2.389	2.249	2.075	1.907	1.718	1.32	1.13	0.818	0.496	0.342
B Category										
Oct	2.452	2.287	2.221	2.088	1.937	1.509	0.998	0.611	0.531	0.434
Nov	3.667	2.664	2.45	2.333	2.159	1.728	1.096	0.706	0.611	0.603
Dec	5.005	3.924	3.132	2.918	2.62	1.968	1.278	0.861	0.744	0.734
Jan	4.951	4.711	4.025	3.361	3.017	2.233	1.538	1.113	0.951	0.611
Feb	4.641	4.611	4.198	3.677	2.906	2.207	1.569	1.225	1.04	0.858
Mar	5.672	5.471	5.14	4.664	3.832	2.688	1.916	1.574	1.303	1.058
Apr	5.237	5.006	4.494	4.071	3.495	2.597	1.809	1.45	1.114	0.75
May	4.363	4.126	3.869	3.792	3.18	2.545	1.757	1.457	1.037	0.291
Jun	3.287	3.166	3.01	2.47	2.195	1.91	1.435	1.001	0.776	0.186
Jul	2.86	2.467	2.17	1.8	1.67	1.31	1.115	0.723	0.569	0.2
Aug	2.603	2.306	2.14	1.82	1.5	1.17	0.957	0.567	0.483	0.19
Sep	2.273	2.142	1.969	1.862	1.718	1.32	0.905	0.494	0.409	0.342
B/C Category										
Oct	2.001	1.954	1.953	1.673	1.119	0.589	0.476	0.476	0.472	0.434
Nov	2.905	2.222	2.092	1.809	1.245	0.759	0.553	0.538	0.538	0.533
Dec	3.81	3.065	2.529	2.15	1.503	0.935	0.71	0.657	0.649	0.642
Jan	3.766	3.528	3.011	2.37	1.722	1.196	0.997	0.871	0.81	0.611
Feb	3.54	3.369	2.98	2.41	1.658	1.3	1.132	0.974	0.877	0.748
Mar	4.223	3.954	3.507	2.866	2.085	1.802	1.509	1.271	1.083	0.918
Apr	3.997	3.696	3.187	2.64	1.986	1.656	1.394	1.162	0.937	0.75
May	3.386	3.179	2.926	2.563	1.907	1.562	1.279	1.169	0.88	0.291
Jun	2.642	2.556	2.46	2.095	1.51	1.073	0.902	0.779	0.682	0.186
Jul	2.345	2.094	2.058	1.8	1.292	0.766	0.594	0.542	0.503	0.2
Aug	2.151	1.949	1.805	1.617	1.114	0.616	0.437	0.433	0.431	0.19
Sep	1.897	1.849	1.786	1.515	0.984	0.489	0.403	0.384	0.369	0.342

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
C Category										
Oct	*1.836*	*1.807*	*1.591*	*1.089*	*0.63*	*0.447*	*0.447*	*0.446*	*0.442*	*0.424*
Nov	*2.469*	*2.006*	*1.679*	*1.191*	*0.751*	*0.596*	*0.512*	*0.502*	*0.502*	*0.496*
Dec	*2.946*	*2.511*	*1.972*	*1.441*	*0.988*	*0.752*	*0.648*	*0.606*	*0.6*	*0.594*
Jan	*2.935*	*2.707*	*2.233*	*1.614*	*1.234*	*0.99*	*0.894*	*0.793*	*0.739*	*0.611*
Feb	*2.773*	*2.508*	*2.14*	*1.676*	*1.234*	*1.097*	*1.003*	*0.879*	*0.795*	*0.685*
Mar	*3.089*	*2.849*	*2.453*	*2.032*	*1.815*	*1.565*	*1.328*	*1.139*	*0.972*	*0.849*
Apr	*3.139*	*2.778*	*2.297*	*1.86*	*1.604*	*1.432*	*1.228*	*1.046*	*0.848*	*0.75*
May	*2.77*	*2.568*	*2.202*	*1.777*	*1.458*	*1.334*	*1.133*	*1.052*	*0.8*	*0.291*
Jun	*2.331*	*2.212*	*1.916*	*1.408*	*1.012*	*0.88*	*0.811*	*0.712*	*0.627*	*0.186*
Jul	*2.154*	*1.934*	*1.664*	*1.211*	*0.781*	*0.599*	*0.549*	*0.505*	*0.47*	*0.2*
Aug	*2.008*	*1.792*	*1.445*	*1.05*	*0.626*	*0.468*	*0.411*	*0.406*	*0.405*	*0.19*
Sep	*1.809*	*1.765*	*1.456*	*0.976*	*0.488*	*0.402*	*0.38*	*0.363*	*0.35*	*0.325*
C/D Category										
Oct	*1.526*	*1.254*	*0.973*	*0.573*	*0.476*	*0.418*	*0.417*	*0.417*	*0.413*	*0.403*
Nov	*1.911*	*1.442*	*1.051*	*0.675*	*0.582*	*0.544*	*0.476*	*0.476*	*0.475*	*0.471*
Dec	*2.075*	*1.772*	*1.291*	*0.91*	*0.788*	*0.676*	*0.593*	*0.572*	*0.571*	*0.565*
Jan	*2.113*	*1.906*	*1.56*	*1.11*	*1.01*	*0.874*	*0.804*	*0.716*	*0.674*	*0.59*
Feb	*2.006*	*1.768*	*1.574*	*1.313*	*1.025*	*0.962*	*0.893*	*0.785*	*0.72*	*0.654*
Mar	*2.053*	*1.99*	*1.886*	*1.737*	*1.547*	*1.346*	*1.173*	*1.008*	*0.868*	*0.822*
Apr	*2.288*	*1.962*	*1.693*	*1.49*	*1.357*	*1.237*	*1.086*	*0.931*	*0.79*	*0.75*
May	*2.095*	*1.828*	*1.529*	*1.323*	*1.214*	*1.158*	*1.007*	*0.935*	*0.76*	*0.291*
Jun	*1.881*	*1.587*	*1.257*	*0.894*	*0.814*	*0.781*	*0.732*	*0.645*	*0.575*	*0.186*
Jul	*1.794*	*1.394*	*1.031*	*0.68*	*0.606*	*0.548*	*0.506*	*0.468*	*0.438*	*0.2*
Aug	*1.697*	*1.291*	*0.913*	*0.542*	*0.473*	*0.435*	*0.386*	*0.381*	*0.38*	*0.19*
Sep	*1.555*	*1.263*	*0.876*	*0.437*	*0.399*	*0.377*	*0.358*	*0.342*	*0.33*	*0.309*
D Category										
Oct	*0.938*	*0.682*	*0.489*	*0.459*	*0.44*	*0.392*	*0.392*	*0.391*	*0.389*	*0.38*
Nov	*1.277*	*0.809*	*0.567*	*0.544*	*0.528*	*0.496*	*0.453*	*0.452*	*0.452*	*0.447*
Dec	*1.582*	*1.181*	*0.787*	*0.74*	*0.699*	*0.61*	*0.546*	*0.545*	*0.544*	*0.538*
Jan	*1.586*	*1.426*	*1.117*	*0.909*	*0.88*	*0.776*	*0.715*	*0.643*	*0.637*	*0.566*
Feb	*1.504*	*1.395*	*1.233*	*1.085*	*0.885*	*0.842*	*0.784*	*0.697*	*0.68*	*0.627*
Mar	*1.712*	*1.659*	*1.569*	*1.442*	*1.308*	*1.166*	*1.018*	*0.876*	*0.832*	*0.796*
Apr	*1.709*	*1.523*	*1.322*	*1.243*	*1.155*	*1.074*	*0.946*	*0.823*	*0.754*	*0.728*
May	*1.471*	*1.254*	*1.099*	*1.098*	*1.043*	*1.01*	*0.882*	*0.825*	*0.729*	*0.291*
Jun	*1.202*	*0.96*	*0.769*	*0.741*	*0.718*	*0.697*	*0.653*	*0.582*	*0.543*	*0.186*
Jul	*1.092*	*0.749*	*0.554*	*0.553*	*0.549*	*0.501*	*0.464*	*0.431*	*0.412*	*0.2*
Aug	*1.015*	*0.701*	*0.506*	*0.439*	*0.437*	*0.404*	*0.361*	*0.358*	*0.357*	*0.19*
Sep	*0.911*	*0.647*	*0.416*	*0.394*	*0.373*	*0.353*	*0.335*	*0.321*	*0.31*	*0.293*
Category Total Flow Assurance curves (mill. m^3)										
A Category										
Oct	*5.723*	*4.3*	*3.085*	*2.82*	*2.315*	*2.07*	*1.78*	*1.55*	*0.903*	*0.434*
Nov	*9.843*	*6.27*	*4.97*	*4.05*	*3.405*	*3.02*	*2.36*	*1.87*	*0.967*	*0.727*
Dec	*11.075*	*7.864*	*5.758*	*4.907*	*3.92*	*3.31*	*2.91*	*2.201*	*1.116*	*0.76*
Jan	*12.74*	*9.746*	*7.339*	*5.901*	*5.275*	*4.18*	*3.78*	*2.612*	*1.293*	*0.611*
Feb	*14.935*	*11.149*	*8.435*	*6.75*	*5.925*	*5.28*	*4.25*	*2.923*	*1.33*	*0.868*
Mar	*13.229*	*10.474*	*8.276*	*6.994*	*6.26*	*5.21*	*4.171*	*2.802*	*1.52*	*1.058*
Apr	*10.299*	*8.312*	*6.135*	*5.08*	*4.72*	*4.08*	*3.255*	*2.409*	*1.381*	*0.75*

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
May	*4.891*	*4.6*	*4.156*	*3.82*	*3.18*	*2.88*	*2.355*	*1.76*	*1.28*	*0.291*
Jun	*3.776*	*3.41*	*3.01*	*2.47*	*2.195*	*1.91*	*1.615*	*1.17*	*0.8*	*0.186*
Jul	*3.331*	*2.84*	*2.17*	*1.8*	*1.67*	*1.31*	*1.115*	*0.89*	*0.66*	*0.2*
Aug	*3.049*	*2.651*	*2.22*	*1.82*	*1.5*	*1.17*	*0.965*	*0.73*	*0.54*	*0.19*
Sep	*3.755*	*2.87*	*2.315*	*1.94*	*1.76*	*1.32*	*1.13*	*0.89*	*0.68*	*0.342*
A/B Category										
Oct	*5.236*	*4.06*	*3.085*	*2.82*	*2.315*	*2.07*	*1.78*	*1.288*	*0.662*	*0.434*
Nov	*9.099*	*6.088*	*4.77*	*4.05*	*3.405*	*3.02*	*2.36*	*1.73*	*0.733*	*0.628*
Dec	*10.353*	*7.343*	*5.426*	*4.668*	*3.92*	*3.31*	*2.831*	*1.865*	*0.883*	*0.76*
Jan	*11.891*	*9.169*	*7.015*	*5.637*	*5.242*	*4.18*	*3.428*	*2.289*	*1.092*	*0.611*
Feb	*13.937*	*10.528*	*8.164*	*6.712*	*5.87*	*5.191*	*3.93*	*2.639*	*1.17*	*0.868*
Mar	*12.426*	*9.886*	*8.059*	*6.823*	*6.168*	*5.055*	*3.573*	*2.582*	*1.407*	*1.058*
Apr	*9.619*	*7.875*	*6.135*	*5.08*	*4.72*	*4.08*	*2.984*	*2.178*	*1.228*	*0.75*
May	*4.558*	*4.349*	*4.037*	*3.82*	*3.18*	*2.88*	*2.005*	*1.603*	*1.141*	*0.291*
Jun	*3.446*	*3.335*	*3.01*	*2.47*	*2.195*	*1.91*	*1.615*	*1.17*	*0.8*	*0.186*
Jul	*3.005*	*2.591*	*2.17*	*1.8*	*1.67*	*1.31*	*1.115*	*0.89*	*0.66*	*0.2*
Aug	*2.737*	*2.422*	*2.215*	*1.82*	*1.5*	*1.17*	*0.965*	*0.73*	*0.54*	*0.19*
Sep	*3.572*	*2.87*	*2.315*	*1.94*	*1.76*	*1.32*	*1.13*	*0.89*	*0.501*	*0.342*
B Category										
Oct	*4.907*	*3.819*	*3.085*	*2.82*	*2.315*	*2.07*	*1.575*	*0.949*	*0.542*	*0.434*
Nov	*8.533*	*5.702*	*4.484*	*3.937*	*3.405*	*3.02*	*2.241*	*1.376*	*0.632*	*0.603*
Dec	*9.757*	*6.89*	*5.118*	*4.484*	*3.92*	*3.31*	*2.396*	*1.514*	*0.764*	*0.734*
Jan	*11.167*	*8.591*	*6.623*	*5.41*	*4.971*	*4.065*	*3*	*1.968*	*0.978*	*0.611*
Feb	*13.018*	*9.84*	*7.699*	*6.438*	*5.539*	*4.676*	*3.54*	*2.378*	*1.076*	*0.858*
Mar	*11.706*	*9.238*	*7.661*	*6.652*	*5.728*	*4.467*	*3.335*	*2.404*	*1.33*	*1.058*
Apr	*9.075*	*7.402*	*6.098*	*5.08*	*4.698*	*3.729*	*2.712*	*1.978*	*1.131*	*0.75*
May	*4.363*	*4.126*	*3.869*	*3.792*	*3.18*	*2.545*	*1.757*	*1.457*	*1.037*	*0.291*
Jun	*3.287*	*3.166*	*3.01*	*2.47*	*2.195*	*1.91*	*1.435*	*1.001*	*0.776*	*0.186*
Jul	*2.86*	*2.467*	*2.17*	*1.8*	*1.67*	*1.31*	*1.115*	*0.723*	*0.569*	*0.2*
Aug	*2.603*	*2.306*	*2.14*	*1.82*	*1.5*	*1.17*	*0.957*	*0.567*	*0.483*	*0.19*
Sep	*3.365*	*2.824*	*2.315*	*1.94*	*1.76*	*1.32*	*1.13*	*0.644*	*0.414*	*0.342*
B/C Category										
Oct	*4.262*	*3.365*	*2.898*	*2.418*	*1.83*	*1.255*	*1.008*	*0.787*	*0.482*	*0.434*
Nov	*7.387*	*5.019*	*3.965*	*3.286*	*2.654*	*2.08*	*1.607*	*1.155*	*0.557*	*0.533*
Dec	*8.186*	*5.797*	*4.358*	*3.592*	*2.878*	*2.225*	*1.739*	*1.259*	*0.668*	*0.642*
Jan	*9.491*	*7.101*	*5.403*	*4.257*	*3.521*	*2.884*	*2.344*	*1.658*	*0.835*	*0.611*
Feb	*11.255*	*8.184*	*6.204*	*4.953*	*4.083*	*3.574*	*2.947*	*2.035*	*0.91*	*0.748*
Mar	*9.78*	*7.422*	*5.829*	*4.698*	*3.831*	*3.44*	*2.816*	*2.035*	*1.107*	*0.918*
Apr	*7.531*	*5.902*	*4.664*	*3.805*	*3.096*	*2.698*	*2.226*	*1.648*	*0.952*	*0.75*
May	*3.386*	*3.179*	*2.926*	*2.563*	*1.907*	*1.562*	*1.279*	*1.169*	*0.88*	*0.291*
Jun	*2.642*	*2.556*	*2.46*	*2.095*	*1.51*	*1.073*	*0.902*	*0.779*	*0.682*	*0.186*
Jul	*2.345*	*2.094*	*2.058*	*1.8*	*1.292*	*0.766*	*0.594*	*0.542*	*0.503*	*0.2*
Aug	*2.151*	*1.949*	*1.805*	*1.617*	*1.114*	*0.616*	*0.437*	*0.433*	*0.431*	*0.19*
Sep	*2.902*	*2.477*	*2.207*	*1.846*	*1.3*	*0.786*	*0.64*	*0.522*	*0.374*	*0.342*
C Category										
Oct	*3.911*	*3.102*	*2.458*	*1.773*	*1.282*	*1.059*	*0.935*	*0.731*	*0.451*	*0.424*
Nov	*6.582*	*4.573*	*3.398*	*2.546*	*2.043*	*1.809*	*1.479*	*1.068*	*0.519*	*0.496*
Dec	*6.962*	*5.017*	*3.65*	*2.764*	*2.25*	*1.936*	*1.593*	*1.158*	*0.617*	*0.594*

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Jan	8.188	5.986	4.429	3.345	2.885	2.538	2.13	1.516	0.762	0.611
Feb	9.853	6.927	5.099	4.009	3.459	3.184	2.669	1.853	0.825	0.685
Mar	8.188	6.032	4.584	3.713	3.417	3.069	2.528	1.841	0.995	0.849
Apr	6.382	4.803	3.652	2.929	2.624	2.388	1.991	1.492	0.862	0.75
May	2.77	2.568	2.202	1.777	1.458	1.334	1.133	1.052	0.8	0.291
Jun	2.331	2.212	1.916	1.408	1.012	0.88	0.811	0.712	0.627	0.186
Jul	2.154	1.934	1.664	1.211	0.781	0.599	0.549	0.505	0.47	0.2
Aug	2.008	1.792	1.445	1.05	0.626	0.468	0.411	0.406	0.405	0.19
Sep	2.732	2.341	1.842	1.28	0.778	0.674	0.598	0.49	0.354	0.325
C/D Category										
Oct	3.422	2.438	1.766	1.198	1.072	0.977	0.863	0.678	0.422	0.403
Nov	5.671	3.789	2.622	1.914	1.764	1.652	1.36	0.993	0.492	0.471
Dec	5.746	4.063	2.825	2.12	1.942	1.758	1.456	1.077	0.587	0.565
Jan	6.915	4.904	3.567	2.693	2.52	2.29	1.934	1.376	0.695	0.59
Feb	8.478	5.808	4.278	3.446	3.059	2.869	2.415	1.676	0.748	0.654
Mar	6.715	4.9	3.835	3.273	3.012	2.72	2.27	1.649	0.888	0.822
Apr	5.252	3.813	2.932	2.467	2.289	2.111	1.783	1.338	0.803	0.75
May	2.095	1.828	1.529	1.323	1.214	1.158	1.007	0.935	0.76	0.291
Jun	1.881	1.587	1.257	0.894	0.814	0.781	0.732	0.645	0.575	0.186
Jul	1.794	1.394	1.031	0.68	0.606	0.548	0.506	0.468	0.438	0.2
Aug	1.697	1.291	0.913	0.542	0.473	0.435	0.386	0.381	0.38	0.19
Sep	2.399	1.79	1.229	0.715	0.665	0.626	0.556	0.458	0.333	0.309
D Category										
Oct	2.664	1.76	1.21	1.028	0.982	0.9	0.798	0.629	0.397	0.38
Nov	4.698	2.945	1.997	1.672	1.603	1.505	1.258	0.923	0.466	0.447
Dec	4.923	3.266	2.183	1.841	1.749	1.595	1.332	1.004	0.558	0.538
Jan	5.957	4.154	2.944	2.35	2.253	2.064	1.743	1.244	0.656	0.566
Feb	7.393	5.071	3.695	3.027	2.736	2.579	2.169	1.508	0.706	0.627
Mar	5.954	4.306	3.342	2.84	2.641	2.416	2.016	1.46	0.85	0.796
Apr	4.407	3.207	2.449	2.132	2.003	1.87	1.58	1.194	0.766	0.728
May	1.471	1.254	1.099	1.098	1.043	1.01	0.882	0.825	0.729	0.291
Jun	1.202	0.96	0.769	0.741	0.718	0.697	0.653	0.582	0.543	0.186
Jul	1.092	0.749	0.554	0.553	0.549	0.501	0.464	0.431	0.412	0.2
Aug	1.015	0.701	0.506	0.439	0.437	0.404	0.361	0.358	0.357	0.19
Sep	1.679	1.126	0.737	0.648	0.614	0.579	0.516	0.427	0.313	0.293

16.3 MG_R_EWR1: uMNGENI RIVER

16.3.1 Hydrology data summary

Natural Flows:				
Area (km^2)	**MAR**	**Ann.SD**	**Q75**	**Ann. CV**
	(m^3 * 10^6)			
0.0	79.22	38.35	2.26	0.48
% Zero flows	0.0			
Baseflow Parameters:			A	0.955
			B	0.43
BFI				0.46
Hydro Index				3.1

Present Day Flows:				
Area (km^2)	**MAR**	**Ann.SD**	**Q75**	**Ann. CV**
	(m^3 * 10^6)			
0	60.46	37.23	0.83	0.62
% Zero flows	0.0			
Baseflow Parameters:			A	0.955
			B	0.43
BFI				0.34
Hydro Index				6.5

MONTH	MEAN	SD	CV		MONTH	MEAN	SD	CV
	(m³ * 10⁶)					(m³ * 10⁶)		
Oct	4.37	5.35	1.22		Oct	2.29	4.82	2.1
Nov	5.81	4.41	0.76		Nov	3.8	3.98	1.05
Dec	9.36	8.91	0.95		Dec	7.5	8.4	1.12
Jan	11.43	9.23	0.81		Jan	10.15	9.3	0.92
Feb	13.3	10.63	0.8		Feb	12.29	10.45	0.85
Mar	12.45	8.57	0.69		Mar	11.31	8.68	0.77
Apr	7.64	5.62	0.74		Apr	5.61	5.72	1.02
May	4.31	3.37	0.78		May	2.58	3.41	1.32
Jun	2.75	1.43	0.52		Jun	1.32	1.26	0.95
Jul	2.45	1.78	0.73		Jul	1.16	1.71	1.48
Aug	2.3	1.87	0.81		Aug	0.94	1.67	1.78
Sep	3.03	6.03	1.99		Sep	1.5	5.74	3.83

Critical months:	Wet Season	Mar	Dry Season	Sep
Max. baseflows (m^3/s)	2.512		0.93	

16.3.2 Hydraulics data summary

Geomorph. Zone	3
Flood Zone	8
Max. Channel width (m)	29.61
Max. Channel Depth (m)	2.04
Observed Channel XS used	
Observed Rating Curve used	
(Gradients and Roughness n values calibrated)	
Max. Gradient	0.007
Min. Gradient	0.007
Gradient Shape Factor	20
Max. Mannings n	0.11
Min. Mannings n	0.03
n Shape Factor	16

16.3.3 Flow - stressor response data summary

Table of initial SHIFT factors for the Stress Frequency Curves		
Category	**High SHIFT**	**Low SHIFT**
A	0.05	0.05
A/B	0.75	0.1
B	0.1	0.15
B/C	0.15	0.175
C	0.2	0.2
C/D	0.25	0.25
D	0.3	0.3
Perenniality Rules: All Seasons Perennial Forced		
Alignment of maximum stress to Present Day stress D Category Aligned		
Table of flows (m^3/s) v stress index		
Stress	**Wet Season Flow**	**Dry Season Flow**
0	2.633	0.963

1	*1.941*	*0.596*
2	*1.225*	*0.411*
3	*0.464*	*0.275*
4	*0.364*	*0.205*
5	*0.303*	*0.171*
6	*0.243*	*0.137*
7	*0.182*	*0.103*
8	*0.121*	*0.068*
9	*0.061*	*0.034*
10	*0*	*0*

16.3.4 High flow estimation summary details

No High flows when natural high flows are < 20% of total flows							
Maximum high flows are 400% greater than normal high flows							
Table of normal high flow requirements (Mill. m^3)							
Category	**A**	**A/B**	**B**	**B/C**	**C**	**C/D**	**D**
Annual	*9.014*	*8.502*	*7.997*	*7.499*	*7.007*	*6.522*	*6.044*
Oct	*0.54*	*0.509*	*0.479*	*0.449*	*0.42*	*0.391*	*0.362*
Nov	*1.168*	*1.102*	*1.036*	*0.972*	*0.908*	*0.845*	*0.783*
Dec	*1.654*	*1.56*	*1.468*	*1.376*	*1.286*	*1.197*	*1.109*
Jan	*1.892*	*1.785*	*1.679*	*1.574*	*1.471*	*1.369*	*1.269*
Feb	*1.516*	*1.43*	*1.345*	*1.261*	*1.178*	*1.097*	*1.016*
Mar	*1.462*	*1.379*	*1.297*	*1.216*	*1.137*	*1.058*	*0.98*
Apr	*0.782*	*0.738*	*0.694*	*0.651*	*0.608*	*0.566*	*0.525*
May	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Jun	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Jul	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Aug	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Sep	*0*	*0*	*0*	*0*	*0*	*0*	*0*

16.3.5 Final Reserve summary details

EWR Flows are constrained to be below Natural or Present Day Flows				
Long term mean flow requirements (Mill. m^3 and %MAR)				
Category	**Low Flows**		**Total Flows**	
	Mill. m^3	**%MAR**	**Mill. m^3**	**%MAR**
A	*22.386*	*28.3*	*34.456*	*43.5*
A/B	*11.391*	*14.4*	*23.403*	*29.5*
B	*15.603*	*19.7*	*26.715*	*33.7*
B/C	*13.068*	*16.5*	*23.568*	*29.8*
C	*10.876*	*13.7*	*20.74*	*26.2*
C/D	*8.013*	*10.1*	*17.221*	*21.7*
D	*6.092*	*7.7*	*14.635*	*18.5*

16.3.6 Flow duration and Reserve assurance tables

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Natural Total flow duration curve (mill. m^3)										
Oct	*9.054*	*4.842*	*3.8*	*3.188*	*2.805*	*2.46*	*2.149*	*1.772*	*1.43*	*0.912*
Nov	*12.136*	*7.238*	*6.17*	*5.536*	*4.535*	*4.176*	*3.173*	*2.6*	*2.192*	*1.008*

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Dec	19.38	14.188	9.772	8.544	7.125	5.57	4.095	2.974	2.412	1.136
Jan	25.712	15.088	12.027	10.712	9.115	7.172	6.299	4.676	3.288	1.675
Feb	29.25	21.622	14.686	12.294	9.36	8.034	6.712	5.732	3.444	1.417
Mar	23.137	16.854	13.482	12.23	9.725	9.092	8.157	6.43	4.299	2.271
Apr	13.378	10.12	7.882	7.366	6.615	5.49	4.926	4.582	3.075	1.943
May	5.851	5.266	4.758	3.968	3.525	3.268	2.832	2.554	2.194	1.473
Jun	4.414	3.436	3.05	2.786	2.59	2.288	1.995	1.7	1.376	1.027
Jul	4.073	3.124	2.645	2.394	2.21	1.74	1.523	1.252	0.981	0.617
Aug	3.489	3.022	2.692	2.272	2.055	1.804	1.446	1.292	0.823	0.644
Sep	4.064	3.388	2.699	2.22	2.045	1.812	1.506	1.178	0.88	0.527
Natural Baseflow flow duration curve (mill. m^3)										
Oct	3.235	2.822	2.29	1.979	1.846	1.67	1.367	1.192	0.959	0.603
Nov	3.637	3.19	2.763	2.417	2.221	2.069	1.751	1.543	1.154	0.769
Dec	5.698	4.086	3.554	3.15	2.791	2.446	2.197	1.897	1.208	0.887
Jan	7.357	5.166	4.501	3.799	3.343	2.745	2.553	2.07	1.591	1.081
Feb	8.507	6.052	5.039	4.31	4.011	3.631	3.116	2.538	2.054	1.25
Mar	7.461	5.615	4.997	4.538	4.285	3.873	3.535	3.01	2.42	1.677
Apr	6.596	5.021	4.612	4.246	3.937	3.556	3.153	2.7	2.159	1.665
May	5.462	4.282	4.058	3.463	3.152	2.836	2.529	2.14	1.772	1.465
Jun	4.16	3.296	2.826	2.688	2.485	2.074	1.833	1.668	1.376	1.027
Jul	3.947	2.77	2.557	2.316	2.14	1.74	1.523	1.252	0.981	0.617
Aug	3.093	2.678	2.375	2.082	1.845	1.674	1.368	1.111	0.78	0.641
Sep	3.036	2.409	2.159	1.95	1.71	1.512	1.311	1	0.851	0.527
Category Low Flow Assurance curves (mill. m^3)										
A Category										
Oct	2.139	1.891	1.434	1.201	0.902	0.708	0.553	0.282	0.141	0.038
Nov	2.307	2.152	1.908	1.49	1.281	1.1	0.899	0.812	0.677	0.229
Dec	4.023	3.508	2.999	2.553	2.057	1.63	1.306	1.008	0.738	0.584
Jan	5.068	4.839	4.54	3.658	3.04	2.121	1.656	1.164	0.966	0.575
Feb	5.403	5.243	4.926	4.31	3.92	3.135	2.173	1.146	0.988	0.32
Mar	5.412	5.162	4.803	3.723	3.264	2.69	2.146	1.675	1.541	0.639
Apr	4.557	4.539	4.537	4.207	3.929	3.053	2.085	1.456	1.184	0.362
May	3.636	3.19	2.854	2.164	1.69	1.438	1.181	1.02	0.655	0.156
Jun	2.381	1.644	1.412	1.196	1.125	0.964	0.74	0.542	0.363	0.05
Jul	2.156	1.448	1.131	0.93	0.84	0.552	0.44	0.25	0.1	0.037
Aug	1.598	1.33	0.997	0.806	0.64	0.482	0.292	0.136	0.051	0.02
Sep	1.83	1.322	0.94	0.666	0.545	0.386	0.186	0.102	0.041	0
A/B Category										
Oct	1.377	0.914	0.473	0.278	0.041	0.04	0.04	0.037	0.019	0.012
Nov	1.518	1.123	0.816	0.412	0.165	0.131	0.131	0.121	0.065	0.041
Dec	2.964	2.248	1.631	1.063	0.441	0.294	0.273	0.223	0.081	0.06
Jan	3.818	3.483	2.937	1.806	0.846	0.464	0.416	0.328	0.199	0.092
Feb	4.393	4.018	3.374	2.343	1.09	0.857	0.682	0.494	0.308	0.113
Mar	4.223	3.672	3.046	1.537	0.729	0.517	0.429	0.334	0.221	0.104
Apr	3.474	3.097	2.906	2.159	1.201	0.79	0.519	0.286	0.192	0.094
May	2.571	2.246	2.142	1.43	0.663	0.461	0.435	0.376	0.255	0.092
Jun	1.703	1.206	0.874	0.611	0.269	0.163	0.162	0.154	0.12	0.05
Jul	1.549	0.919	0.66	0.361	0.128	0.059	0.055	0.049	0.039	0.036

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Aug	*1.298*	*0.856*	*0.525*	*0.221*	*0.077*	*0.076*	*0.07*	*0.069*	*0.051*	*0.017*
Sep	*1.151*	*0.646*	*0.38*	*0.125*	*0*	*0*	*0*	*0*	*0*	*0*
B Category										
Oct	*1.414*	*1.283*	*0.966*	*0.803*	*0.634*	*0.553*	*0.512*	*0.282*	*0.141*	*0.038*
Nov	*1.53*	*1.458*	*1.277*	*0.987*	*0.834*	*0.692*	*0.628*	*0.616*	*0.542*	*0.229*
Dec	*2.711*	*2.368*	*1.992*	*1.661*	*1.244*	*0.905*	*0.783*	*0.736*	*0.594*	*0.558*
Jan	*3.427*	*3.256*	*2.995*	*2.352*	*1.747*	*1.08*	*0.899*	*0.832*	*0.782*	*0.555*
Feb	*3.692*	*3.523*	*3.232*	*2.771*	*2.104*	*1.254*	*1.01*	*0.874*	*0.79*	*0.32*
Mar	*3.674*	*3.469*	*3.167*	*2.418*	*1.954*	*1.452*	*1.279*	*1.246*	*1.24*	*0.639*
Apr	*3.079*	*2.994*	*2.987*	*2.692*	*2.158*	*1.402*	*1.165*	*1.165*	*1.165*	*0.362*
May	*2.416*	*2.416*	*2.403*	*2.008*	*1.527*	*1.072*	*0.965*	*0.963*	*0.655*	*0.156*
Jun	*1.69*	*1.527*	*1.335*	*1.194*	*0.989*	*0.731*	*0.664*	*0.542*	*0.363*	*0.05*
Jul	*1.566*	*1.29*	*1.131*	*0.93*	*0.795*	*0.552*	*0.44*	*0.25*	*0.1*	*0.037*
Aug	*1.309*	*1.213*	*0.997*	*0.783*	*0.64*	*0.482*	*0.292*	*0.136*	*0.051*	*0.02*
Sep	*1.213*	*1.047*	*0.854*	*0.663*	*0.539*	*0.386*	*0.186*	*0.102*	*0.041*	*0*
B/C Category										
Oct	*1.257*	*1.122*	*0.808*	*0.671*	*0.535*	*0.466*	*0.412*	*0.282*	*0.141*	*0.038*
Nov	*1.358*	*1.268*	*1.067*	*0.812*	*0.667*	*0.569*	*0.516*	*0.505*	*0.43*	*0.229*
Dec	*2.389*	*2.052*	*1.658*	*1.324*	*0.934*	*0.725*	*0.659*	*0.615*	*0.469*	*0.459*
Jan	*2.984*	*2.81*	*2.488*	*1.834*	*1.241*	*0.846*	*0.768*	*0.708*	*0.625*	*0.443*
Feb	*3.236*	*3.038*	*2.683*	*2.127*	*1.349*	*1.022*	*0.875*	*0.775*	*0.677*	*0.32*
Mar	*3.226*	*2.996*	*2.64*	*1.924*	*1.454*	*1.157*	*1.07*	*1.036*	*0.98*	*0.639*
Apr	*2.706*	*2.563*	*2.457*	*2.087*	*1.472*	*1.058*	*0.933*	*0.921*	*0.92*	*0.362*
May	*2.121*	*2.068*	*1.994*	*1.58*	*1.107*	*0.845*	*0.781*	*0.765*	*0.652*	*0.156*
Jun	*1.498*	*1.33*	*1.112*	*0.972*	*0.767*	*0.596*	*0.55*	*0.541*	*0.363*	*0.05*
Jul	*1.391*	*1.127*	*0.964*	*0.784*	*0.644*	*0.503*	*0.438*	*0.25*	*0.1*	*0.037*
Aug	*1.16*	*1.06*	*0.855*	*0.658*	*0.551*	*0.47*	*0.292*	*0.136*	*0.051*	*0.02*
Sep	*1.076*	*0.922*	*0.702*	*0.559*	*0.473*	*0.386*	*0.186*	*0.102*	*0.041*	*0*
C Category										
Oct	*1.124*	*0.973*	*0.695*	*0.563*	*0.46*	*0.385*	*0.319*	*0.282*	*0.141*	*0.038*
Nov	*1.209*	*1.092*	*0.899*	*0.669*	*0.555*	*0.478*	*0.411*	*0.395*	*0.318*	*0.229*
Dec	*2.083*	*1.739*	*1.355*	*1.022*	*0.744*	*0.62*	*0.55*	*0.498*	*0.35*	*0.335*
Jan	*2.535*	*2.35*	*1.986*	*1.353*	*0.943*	*0.734*	*0.659*	*0.59*	*0.49*	*0.331*
Feb	*2.769*	*2.529*	*2.118*	*1.482*	*1.054*	*0.904*	*0.789*	*0.676*	*0.564*	*0.32*
Mar	*2.779*	*2.512*	*2.12*	*1.485*	*1.155*	*0.993*	*0.892*	*0.83*	*0.728*	*0.511*
Apr	*2.341*	*2.135*	*1.952*	*1.533*	*1.101*	*0.933*	*0.801*	*0.711*	*0.676*	*0.362*
May	*1.858*	*1.731*	*1.608*	*1.191*	*0.862*	*0.732*	*0.67*	*0.63*	*0.569*	*0.156*
Jun	*1.33*	*1.143*	*0.931*	*0.779*	*0.625*	*0.503*	*0.441*	*0.431*	*0.363*	*0.05*
Jul	*1.24*	*0.976*	*0.819*	*0.652*	*0.539*	*0.418*	*0.343*	*0.25*	*0.1*	*0.037*
Aug	*1.032*	*0.918*	*0.733*	*0.563*	*0.471*	*0.391*	*0.292*	*0.136*	*0.051*	*0.02*
Sep	*0.972*	*0.797*	*0.62*	*0.494*	*0.41*	*0.335*	*0.186*	*0.102*	*0.041*	*0*
C/D Category										
Oct	*0.898*	*0.768*	*0.573*	*0.471*	*0.38*	*0.297*	*0.225*	*0.197*	*0.141*	*0.038*
Nov	*0.952*	*0.835*	*0.683*	*0.548*	*0.462*	*0.38*	*0.306*	*0.278*	*0.202*	*0.149*
Dec	*1.504*	*1.215*	*0.92*	*0.77*	*0.627*	*0.507*	*0.432*	*0.371*	*0.226*	*0.206*
Jan	*1.73*	*1.525*	*1.194*	*0.962*	*0.804*	*0.614*	*0.537*	*0.458*	*0.351*	*0.219*
Feb	*1.832*	*1.572*	*1.138*	*1.032*	*0.905*	*0.797*	*0.682*	*0.559*	*0.437*	*0.241*
Mar	*1.905*	*1.641*	*1.293*	*1.122*	*0.975*	*0.817*	*0.702*	*0.608*	*0.491*	*0.319*

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Apr	*1.635*	*1.403*	*1.171*	*1.062*	*0.948*	*0.8*	*0.655*	*0.521*	*0.427*	*0.299*
May	*1.371*	*1.203*	*1.033*	*0.869*	*0.732*	*0.613*	*0.543*	*0.497*	*0.414*	*0.156*
Jun	*1.034*	*0.867*	*0.702*	*0.619*	*0.523*	*0.402*	*0.328*	*0.31*	*0.267*	*0.05*
Jul	*0.98*	*0.768*	*0.645*	*0.541*	*0.448*	*0.326*	*0.244*	*0.211*	*0.1*	*0.037*
Aug	*0.807*	*0.726*	*0.596*	*0.48*	*0.389*	*0.304*	*0.231*	*0.136*	*0.051*	*0.02*
Sep	*0.787*	*0.652*	*0.518*	*0.429*	*0.337*	*0.255*	*0.184*	*0.102*	*0.041*	*0*
D Category										
Oct	*0.731*	*0.641*	*0.501*	*0.401*	*0.3*	*0.209*	*0.131*	*0.092*	*0.042*	*0.017*
Nov	*0.761*	*0.685*	*0.59*	*0.468*	*0.374*	*0.284*	*0.202*	*0.162*	*0.086*	*0.052*
Dec	*1.06*	*0.919*	*0.782*	*0.662*	*0.524*	*0.4*	*0.314*	*0.243*	*0.102*	*0.077*
Jan	*1.148*	*1.078*	*0.99*	*0.833*	*0.69*	*0.503*	*0.415*	*0.326*	*0.212*	*0.111*
Feb	*1.093*	*1.056*	*0.992*	*0.894*	*0.805*	*0.699*	*0.575*	*0.442*	*0.31*	*0.146*
Mar	*1.233*	*1.179*	*1.07*	*0.966*	*0.817*	*0.651*	*0.511*	*0.386*	*0.255*	*0.131*
Apr	*1.093*	*1.015*	*0.978*	*0.922*	*0.832*	*0.684*	*0.509*	*0.33*	*0.221*	*0.118*
May	*1.004*	*0.92*	*0.873*	*0.751*	*0.622*	*0.502*	*0.42*	*0.363*	*0.263*	*0.113*
Jun	*0.814*	*0.706*	*0.607*	*0.53*	*0.43*	*0.304*	*0.221*	*0.189*	*0.14*	*0.05*
Jul	*0.786*	*0.644*	*0.561*	*0.461*	*0.36*	*0.234*	*0.147*	*0.103*	*0.052*	*0.037*
Aug	*0.65*	*0.605*	*0.52*	*0.408*	*0.309*	*0.218*	*0.144*	*0.094*	*0.051*	*0.02*
Sep	*0.655*	*0.55*	*0.461*	*0.364*	*0.264*	*0.174*	*0.103*	*0.052*	*0.019*	*0*
Category Total Flow Assurance curves (mill. m^3)										
A Category										
Oct	*4.04*	*2.222*	*1.543*	*1.224*	*0.91*	*0.708*	*0.553*	*0.282*	*0.141*	*0.038*
Nov	*6.47*	*4.872*	*3.789*	*3.137*	*2.463*	*2.192*	*1.733*	*1.306*	*0.684*	*0.229*
Dec	*9.919*	*8.055*	*6.34*	*4.885*	*3.731*	*3.175*	*2.544*	*1.716*	*0.748*	*0.584*
Jan	*11.813*	*10.04*	*8.362*	*6.326*	*4.955*	*3.889*	*3.071*	*1.989*	*0.978*	*0.575*
Feb	*10.807*	*9.41*	*7.988*	*6.447*	*5.454*	*4.551*	*3.307*	*1.807*	*0.997*	*0.32*
Mar	*10.624*	*9.182*	*7.756*	*5.785*	*4.744*	*4.056*	*3.24*	*2.312*	*1.55*	*0.639*
Apr	*7.345*	*6.689*	*6.078*	*5.31*	*4.38*	*3.236*	*2.67*	*1.797*	*1.184*	*0.362*
May	*3.636*	*3.19*	*2.854*	*2.164*	*1.69*	*1.438*	*1.181*	*1.02*	*0.655*	*0.156*
Jun	*2.381*	*1.644*	*1.412*	*1.196*	*1.125*	*0.964*	*0.74*	*0.542*	*0.363*	*0.05*
Jul	*2.156*	*1.448*	*1.131*	*0.93*	*0.84*	*0.552*	*0.44*	*0.25*	*0.1*	*0.037*
Aug	*1.598*	*1.33*	*0.997*	*0.806*	*0.64*	*0.482*	*0.292*	*0.136*	*0.051*	*0.02*
Sep	*1.83*	*1.322*	*0.94*	*0.666*	*0.545*	*0.386*	*0.186*	*0.102*	*0.041*	*0*
A/B Category										
Oct	*3.192*	*2.222*	*1.501*	*0.995*	*0.556*	*0.516*	*0.421*	*0.259*	*0.023*	*0.012*
Nov	*5.444*	*4.151*	*3.041*	*1.965*	*1.28*	*1.161*	*0.955*	*0.602*	*0.072*	*0.041*
Dec	*8.526*	*6.536*	*4.782*	*3.263*	*2.02*	*1.752*	*1.441*	*0.903*	*0.09*	*0.06*
Jan	*10.179*	*8.389*	*6.542*	*4.323*	*2.653*	*2.132*	*1.751*	*1.106*	*0.209*	*0.092*
Feb	*9.49*	*7.948*	*6.262*	*4.36*	*2.537*	*2.193*	*1.752*	*1.117*	*0.316*	*0.113*
Mar	*9.14*	*7.463*	*5.832*	*3.482*	*2.124*	*1.806*	*1.461*	*0.936*	*0.229*	*0.104*
Apr	*6.104*	*5.125*	*4.397*	*3.2*	*1.948*	*1.479*	*1.071*	*0.608*	*0.196*	*0.094*
May	*2.571*	*2.246*	*2.142*	*1.43*	*0.663*	*0.461*	*0.435*	*0.376*	*0.255*	*0.092*
Jun	*1.703*	*1.206*	*0.874*	*0.611*	*0.269*	*0.163*	*0.162*	*0.154*	*0.12*	*0.05*
Jul	*1.549*	*0.919*	*0.66*	*0.361*	*0.128*	*0.059*	*0.055*	*0.049*	*0.039*	*0.036*
Aug	*1.298*	*0.856*	*0.525*	*0.221*	*0.077*	*0.076*	*0.07*	*0.069*	*0.051*	*0.017*
Sep	*1.151*	*0.646*	*0.38*	*0.125*	*0*	*0*	*0*	*0*	*0*	*0*
B Category										
Oct	*3.121*	*2.222*	*1.543*	*1.224*	*0.91*	*0.708*	*0.553*	*0.282*	*0.141*	*0.038*

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Nov	*5.223*	*4.306*	*3.37*	*2.448*	*1.882*	*1.66*	*1.403*	*1.068*	*0.549*	*0.229*
Dec	*7.942*	*6.401*	*4.956*	*3.731*	*2.73*	*2.276*	*1.881*	*1.376*	*0.603*	*0.558*
Jan	*9.411*	*7.87*	*6.386*	*4.719*	*3.446*	*2.648*	*2.155*	*1.564*	*0.792*	*0.555*
Feb	*8.486*	*7.219*	*5.948*	*4.667*	*3.465*	*2.511*	*2.016*	*1.461*	*0.798*	*0.32*
Mar	*8.299*	*7.035*	*5.787*	*4.247*	*3.267*	*2.665*	*2.25*	*1.812*	*1.248*	*0.639*
Apr	*5.553*	*4.901*	*4.389*	*3.671*	*2.861*	*2.05*	*1.684*	*1.467*	*1.169*	*0.362*
May	*2.416*	*2.416*	*2.403*	*2.008*	*1.527*	*1.072*	*0.965*	*0.963*	*0.655*	*0.156*
Jun	*1.69*	*1.527*	*1.335*	*1.194*	*0.989*	*0.731*	*0.664*	*0.542*	*0.363*	*0.05*
Jul	*1.566*	*1.29*	*1.131*	*0.93*	*0.795*	*0.552*	*0.44*	*0.25*	*0.1*	*0.037*
Aug	*1.309*	*1.213*	*0.997*	*0.783*	*0.64*	*0.482*	*0.292*	*0.136*	*0.051*	*0.02*
Sep	*1.213*	*1.047*	*0.854*	*0.663*	*0.539*	*0.386*	*0.186*	*0.102*	*0.041*	*0*
B/C Category										
Oct	*2.858*	*2.222*	*1.543*	*1.224*	*0.91*	*0.708*	*0.553*	*0.282*	*0.141*	*0.038*
Nov	*4.821*	*3.939*	*3.03*	*2.182*	*1.65*	*1.477*	*1.243*	*0.928*	*0.436*	*0.229*
Dec	*7.294*	*5.835*	*4.437*	*3.264*	*2.326*	*2.011*	*1.688*	*1.215*	*0.478*	*0.459*
Jan	*8.595*	*7.136*	*5.667*	*4.053*	*2.834*	*2.317*	*1.946*	*1.395*	*0.635*	*0.443*
Feb	*7.732*	*6.505*	*5.23*	*3.905*	*2.625*	*2.201*	*1.818*	*1.325*	*0.684*	*0.32*
Mar	*7.563*	*6.339*	*5.097*	*3.639*	*2.685*	*2.294*	*1.98*	*1.566*	*0.988*	*0.639*
Apr	*5.026*	*4.352*	*3.772*	*3.004*	*2.13*	*1.666*	*1.42*	*1.204*	*0.924*	*0.362*
May	*2.121*	*2.068*	*1.994*	*1.58*	*1.107*	*0.845*	*0.781*	*0.765*	*0.652*	*0.156*
Jun	*1.498*	*1.33*	*1.112*	*0.972*	*0.767*	*0.596*	*0.55*	*0.541*	*0.363*	*0.05*
Jul	*1.391*	*1.127*	*0.964*	*0.784*	*0.644*	*0.503*	*0.438*	*0.25*	*0.1*	*0.037*
Aug	*1.16*	*1.06*	*0.855*	*0.658*	*0.551*	*0.47*	*0.292*	*0.136*	*0.051*	*0.02*
Sep	*1.076*	*0.922*	*0.702*	*0.559*	*0.473*	*0.386*	*0.186*	*0.102*	*0.041*	*0*
C Category										
Oct	*2.62*	*2.126*	*1.536*	*1.155*	*0.885*	*0.708*	*0.553*	*0.282*	*0.141*	*0.038*
Nov	*4.445*	*3.587*	*2.733*	*1.949*	*1.474*	*1.327*	*1.09*	*0.791*	*0.324*	*0.229*
Dec	*6.667*	*5.273*	*3.952*	*2.835*	*2.045*	*1.822*	*1.512*	*1.059*	*0.357*	*0.335*
Jan	*7.779*	*6.393*	*4.956*	*3.427*	*2.432*	*2.108*	*1.76*	*1.232*	*0.499*	*0.331*
Feb	*6.97*	*5.768*	*4.498*	*3.144*	*2.246*	*2.005*	*1.671*	*1.19*	*0.571*	*0.32*
Mar	*6.831*	*5.637*	*4.416*	*3.088*	*2.305*	*2.055*	*1.743*	*1.326*	*0.735*	*0.511*
Apr	*4.509*	*3.806*	*3.18*	*2.391*	*1.716*	*1.501*	*1.256*	*0.976*	*0.679*	*0.362*
May	*1.858*	*1.731*	*1.608*	*1.191*	*0.862*	*0.732*	*0.67*	*0.63*	*0.569*	*0.156*
Jun	*1.33*	*1.143*	*0.931*	*0.779*	*0.625*	*0.503*	*0.441*	*0.431*	*0.363*	*0.05*
Jul	*1.24*	*0.976*	*0.819*	*0.652*	*0.539*	*0.418*	*0.343*	*0.25*	*0.1*	*0.037*
Aug	*1.032*	*0.918*	*0.733*	*0.563*	*0.471*	*0.391*	*0.292*	*0.136*	*0.051*	*0.02*
Sep	*0.972*	*0.797*	*0.62*	*0.494*	*0.41*	*0.335*	*0.186*	*0.102*	*0.041*	*0*
C/D Category										
Oct	*2.291*	*1.841*	*1.362*	*1.022*	*0.775*	*0.662*	*0.517*	*0.282*	*0.141*	*0.038*
Nov	*3.964*	*3.158*	*2.39*	*1.74*	*1.317*	*1.17*	*0.938*	*0.647*	*0.207*	*0.149*
Dec	*5.771*	*4.504*	*3.338*	*2.457*	*1.838*	*1.625*	*1.327*	*0.893*	*0.233*	*0.206*
Jan	*6.61*	*5.288*	*3.959*	*2.892*	*2.189*	*1.893*	*1.561*	*1.055*	*0.359*	*0.219*
Feb	*5.742*	*4.587*	*3.354*	*2.579*	*2.015*	*1.822*	*1.503*	*1.037*	*0.443*	*0.241*
Mar	*5.677*	*4.549*	*3.43*	*2.614*	*2.045*	*1.805*	*1.493*	*1.07*	*0.498*	*0.319*
Apr	*3.653*	*2.959*	*2.314*	*1.86*	*1.521*	*1.329*	*1.078*	*0.768*	*0.43*	*0.299*
May	*1.371*	*1.203*	*1.033*	*0.869*	*0.732*	*0.613*	*0.543*	*0.497*	*0.414*	*0.156*
Jun	*1.034*	*0.867*	*0.702*	*0.619*	*0.523*	*0.402*	*0.328*	*0.31*	*0.267*	*0.05*
Jul	*0.98*	*0.768*	*0.645*	*0.541*	*0.448*	*0.326*	*0.244*	*0.211*	*0.1*	*0.037*

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Aug	0.807	0.726	0.596	0.48	0.389	0.304	0.231	0.136	0.051	0.02
Sep	0.787	0.652	0.518	0.429	0.337	0.255	0.184	0.102	0.041	0
D Category										
Oct	2.021	1.636	1.232	0.911	0.666	0.547	0.402	0.249	0.044	0.017
Nov	3.552	2.838	2.172	1.572	1.167	1.016	0.787	0.503	0.09	0.052
Dec	5.013	3.968	3.022	2.226	1.646	1.436	1.144	0.727	0.109	0.077
Jan	5.67	4.565	3.553	2.622	1.974	1.688	1.365	0.879	0.219	0.111
Feb	4.717	3.85	3.045	2.327	1.834	1.649	1.335	0.885	0.316	0.146
Mar	4.728	3.874	3.051	2.349	1.81	1.567	1.244	0.814	0.261	0.131
Apr	2.962	2.457	2.037	1.662	1.362	1.174	0.902	0.559	0.224	0.118
May	1.004	0.92	0.873	0.751	0.622	0.502	0.42	0.363	0.263	0.113
Jun	0.814	0.706	0.607	0.53	0.43	0.304	0.221	0.189	0.14	0.05
Jul	0.786	0.644	0.561	0.461	0.36	0.234	0.147	0.103	0.052	0.037
Aug	0.65	0.605	0.52	0.408	0.309	0.218	0.144	0.094	0.051	0.02
Sep	0.655	0.55	0.461	0.364	0.264	0.174	0.103	0.052	0.019	0

16.4 MG_R_EWR3: KARKLOOF RIVER

16.4.1 Hydrology data summary

Natural Flows:						Present Day Flows:				
Area (km^2)	**MAR**	**Ann.SD**	**Q75**	**Ann. CV**		**Area (km^2)**	**MAR**	**Ann.SD**	**Q75**	**Ann. CV**
	(m^3 * 10^6)						**(m^3 * 10^6)**			
0.0	70.11	39.99	1.59	0.57		0	56.5	34.94	0.95	0.62
% Zero flows	0.0					% Zero flows	0.0			
Baseflow Parameters:			A	0.955		Baseflow Parameters:			A	0.955
			B	0.43					B	0.43
BFI				0.43		BFI				0.4
Hydro Index				3.7		Hydro Index				4.7

MONTH	**MEAN**	**SD**	**CV**		**MONTH**	**MEAN**	**SD**	**CV**
	(m^3 * 10^6)					**(m^3 * 10^6)**		
Oct	3.27	6.14	1.88		Oct	2.45	5	2.05
Nov	4.09	4.8	1.17		Nov	3.06	4.18	1.36
Dec	7.07	6.69	0.95		Dec	5.83	6.15	1.06
Jan	10.16	8.8	0.87		Jan	8.64	7.87	0.91
Feb	11.8	8.92	0.76		Feb	10.02	7.81	0.78
Mar	11.69	8.6	0.74		Mar	9.83	7.56	0.77
Apr	7.92	6.11	0.77		Apr	6.29	5.27	0.84
May	4.54	4.33	0.95		May	3.44	3.78	1.1
Jun	2.77	2.57	0.93		Jun	1.97	2.2	1.12
Jul	1.94	1.3	0.67		Jul	1.34	1.16	0.87
Aug	1.75	1.57	0.9		Aug	1.19	1.36	1.15
Sep	3.1	12.58	4.05		Sep	2.45	11.73	4.79

Critical months:	Wet Season	Mar	Dry Season	Sep
Using 20th percentile of FDC of separated baseflows				
Max. baseflows (m^3/s)	2.0192		0.7058	

16.4.2 Hydraulics data summary

Geomorph. Zone	*3*
Flood Zone	*8*
Max. Channel width (m)	*30.38*
Max. Channel Depth (m)	*2.06*
Observed Channel XS used	
Observed Rating Curve used	
(Gradients and Roughness n values calibrated)	
Max. Gradient	*0.013*
Min. Gradient	*0.008*
Gradient Shape Factor	*20*
Max. Mannings n	*0.15*
Min. Mannings n	*0.05*
n Shape Factor	*15*

16.4.3 Flow - stressor response data summary

Table of initial SHIFT factors for the Stress Frequency Curves		
Category	**High SHIFT**	**Low SHIFT**
A	*0.05*	*0.025*
A/B	*0.1*	*0.05*
B	*0.15*	*0.075*
B/C	*0.2*	*0.1*
C	*0.25*	*0.15*
C/D	*0.3*	*0.2*
D	*0.35*	*0.25*
Perenniality Rules: All Seasons Perennial Forced		
Alignment of maximum stress to Present Day stress D Category Aligned		
Table of flows (m^3/s) v stress index		
Stress	**Wet Season Flow**	**Dry Season Flow**
0	*2.084*	*0.733*
1	*1.508*	*0.663*
2	*1.174*	*0.555*
3	*0.91*	*0.446*
4	*0.659*	*0.408*
5	*0.342*	*0.304*
6	*0.274*	*0.223*
7	*0.205*	*0.07*
8	*0.137*	*0.056*
9	*0.068*	*0.012*
10	*0*	*0*

16.4.4 High flow estimation summary details

No High flows when natural high flows are < 20% of total flows							
Maximum high flows are 500% greater than normal high flows							
Table of normal high flow requirements (Mill. m^3)							
Category	**A**	**A/B**	**B**	**B/C**	**C**	**C/D**	**D**
Annual	*8.372*	*7.876*	*7.388*	*6.909*	*6.439*	*5.977*	*5.524*
Oct	*0.313*	*0.294*	*0.276*	*0.258*	*0.241*	*0.223*	*0.207*
Nov	*0.898*	*0.844*	*0.792*	*0.741*	*0.69*	*0.641*	*0.592*

No High flows when natural high flows are < 20% of total flows							
Maximum high flows are 500% greater than normal high flows							
Table of normal high flow requirements (Mill. m^3)							
Category	**A**	**A/B**	**B**	**B/C**	**C**	**C/D**	**D**
Dec	1.441	1.355	1.271	1.189	1.108	1.029	0.951
Jan	1.737	1.634	1.533	1.434	1.336	1.24	1.146
Feb	1.649	1.551	1.455	1.361	1.268	1.177	1.088
Mar	1.445	1.36	1.275	1.193	1.111	1.032	0.954
Apr	0.692	0.651	0.611	0.571	0.532	0.494	0.457
May	0.197	0.186	0.174	0.163	0.152	0.141	0.13
Jun	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0

16.4.5 Final Reserve summary details

EWR Flows are constrained to be below Natural or Present Day Flows				
Long term mean flow requirements (Mill. m^3 and %MAR)				
Category	**Low Flows**		**Total Flows**	
	Mill. m^3	**%MAR**	**Mill. m^3**	**%MAR**
A	21.496	30.7	34.151	48.7
A/B	20.291	28.9	32.317	46.1
B	19.111	27.3	30.489	43.5
B/C	18.02	25.7	28.738	41
C	16.253	23.2	26.329	37.6
C/D	14.536	20.7	23.954	34.2
D	12.907	18.4	21.64	30.9

16.4.6 Flow duration and Reserve assurance tables

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Natural Total flow duration curve (mill. m^3)										
Oct	6.066	2.902	1.96	1.706	1.55	1.374	1.202	1.022	0.846	0.58
Nov	6.966	5.28	3.898	3.25	2.755	2.394	1.922	1.496	1.323	0.871
Dec	15.469	12.118	7.758	6.284	4.795	3.51	2.69	2.34	1.797	0.586
Jan	21.953	15.75	10.877	9.642	8.55	6.246	4.302	3.452	2.264	0.989
Feb	24.444	18.62	14.753	11.134	9.695	7.776	6.119	5.21	3.441	1.201
Mar	23.071	16.348	14.393	11.908	9.75	8.1	6.226	4.684	3.702	1.771
Apr	17.886	10.552	8.519	7.154	5.955	5.608	4.227	3.426	2.509	1.295
May	6.967	5.524	5.105	4.464	3.79	3.226	2.863	2.484	1.522	0.8
Jun	3.899	3.496	2.877	2.676	2.285	2.158	1.75	1.592	1.065	0.604
Jul	2.953	2.464	2.161	1.958	1.705	1.484	1.333	1.152	0.783	0
Aug	2.926	2.256	1.774	1.51	1.37	1.25	1.114	0.91	0.822	0.277
Sep	2.799	2.242	1.767	1.452	1.225	1.054	0.96	0.886	0.66	0
Natural Baseflow flow duration curve (mill. m^3)										
Oct	2.589	1.886	1.531	1.343	1.104	1.006	0.924	0.864	0.622	0.196
Nov	2.59	2.1	1.742	1.609	1.395	1.217	1.13	0.982	0.758	0.515
Dec	4.751	3.54	2.626	2.007	1.76	1.617	1.425	1.195	0.912	0.547
Jan	6.264	4.377	3.577	2.994	2.615	2.205	1.806	1.384	1.057	0.545

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Feb	*7.007*	*4.725*	*4.203*	*3.641*	*3.202*	*2.786*	*2.433*	*2.066*	*1.503*	*0.749*
Mar	*6.211*	*5.399*	*4.615*	*3.919*	*3.608*	*3.291*	*2.836*	*2.333*	*1.98*	*0.935*
Apr	*5.88*	*4.849*	*4.31*	*3.69*	*3.414*	*3.029*	*2.669*	*2.203*	*1.725*	*0.951*
May	*4.862*	*4.005*	*3.518*	*2.982*	*2.865*	*2.712*	*2.393*	*1.789*	*1.367*	*0.799*
Jun	*3.811*	*3.008*	*2.687*	*2.446*	*2.23*	*1.942*	*1.651*	*1.348*	*0.886*	*0.604*
Jul	*2.929*	*2.425*	*2.125*	*1.876*	*1.69*	*1.472*	*1.246*	*1.058*	*0.783*	*0*
Aug	*2.655*	*2.168*	*1.69*	*1.412*	*1.304*	*1.206*	*0.976*	*0.88*	*0.752*	*0.171*
Sep	*2.285*	*1.818*	*1.469*	*1.246*	*1.12*	*0.992*	*0.913*	*0.803*	*0.565*	*0*
Category Low Flow Assurance curves (mill. m^3)										
A Category										
Oct	*2.259*	*1.822*	*1.217*	*1.06*	*0.96*	*0.798*	*0.511*	*0.226*	*0.149*	*0.069*
Nov	*2.377*	*2.001*	*1.716*	*1.527*	*1.284*	*0.939*	*0.623*	*0.301*	*0.24*	*0.226*
Dec	*3.666*	*3.24*	*2.557*	*1.978*	*1.663*	*1.301*	*0.881*	*0.448*	*0.318*	*0.293*
Jan	*4.985*	*4.139*	*3.429*	*2.944*	*2.397*	*1.823*	*1.19*	*0.649*	*0.413*	*0.234*
Feb	*4.902*	*4.22*	*3.532*	*3.187*	*2.693*	*2.124*	*1.658*	*1.219*	*0.685*	*0.465*
Mar	*5.042*	*4.807*	*4.376*	*3.842*	*3.307*	*2.766*	*2.241*	*1.76*	*1.255*	*0.862*
Apr	*4.483*	*4.305*	*3.89*	*3.556*	*3.058*	*2.481*	*1.96*	*1.467*	*0.909*	*0.566*
May	*3.972*	*3.8*	*3.331*	*2.988*	*2.656*	*2.24*	*1.748*	*1.046*	*0.717*	*0.429*
Jun	*2.906*	*2.53*	*2.123*	*1.83*	*1.57*	*1.37*	*1.032*	*0.624*	*0.375*	*0.29*
Jul	*2.138*	*1.818*	*1.427*	*1.24*	*1.025*	*0.904*	*0.756*	*0.347*	*0.206*	*0*
Aug	*1.917*	*1.41*	*1.12*	*0.938*	*0.815*	*0.76*	*0.555*	*0.236*	*0.193*	*0.072*
Sep	*1.796*	*1.388*	*1.09*	*0.922*	*0.745*	*0.634*	*0.473*	*0.169*	*0.118*	*0*
A/B Category										
Oct	*2.185*	*1.769*	*1.217*	*1.06*	*0.96*	*0.749*	*0.454*	*0.202*	*0.131*	*0.057*
Nov	*2.291*	*1.925*	*1.669*	*1.492*	*1.238*	*0.882*	*0.556*	*0.269*	*0.209*	*0.207*
Dec	*3.467*	*3.061*	*2.449*	*1.919*	*1.596*	*1.221*	*0.793*	*0.399*	*0.277*	*0.274*
Jan	*4.672*	*3.851*	*3.226*	*2.811*	*2.276*	*1.708*	*1.079*	*0.579*	*0.353*	*0.204*
Feb	*4.641*	*3.946*	*3.285*	*3.013*	*2.532*	*1.987*	*1.518*	*1.082*	*0.579*	*0.426*
Mar	*4.656*	*4.419*	*4.008*	*3.614*	*3.091*	*2.582*	*2.065*	*1.537*	*1.028*	*0.825*
Apr	*4.158*	*3.984*	*3.61*	*3.352*	*2.867*	*2.319*	*1.795*	*1.29*	*0.765*	*0.503*
May	*3.723*	*3.558*	*3.14*	*2.851*	*2.512*	*2.096*	*1.6*	*0.928*	*0.608*	*0.429*
Jun	*2.874*	*2.53*	*2.123*	*1.83*	*1.57*	*1.37*	*0.932*	*0.558*	*0.345*	*0.29*
Jul	*2.138*	*1.818*	*1.427*	*1.24*	*1.025*	*0.904*	*0.678*	*0.31*	*0.179*	*0*
Aug	*1.917*	*1.41*	*1.12*	*0.938*	*0.815*	*0.76*	*0.494*	*0.212*	*0.168*	*0.062*
Sep	*1.751*	*1.388*	*1.09*	*0.922*	*0.745*	*0.634*	*0.404*	*0.163*	*0.101*	*0*
B Category										
Oct	*2.105*	*1.706*	*1.217*	*1.06*	*0.96*	*0.7*	*0.394*	*0.187*	*0.112*	*0.047*
Nov	*2.198*	*1.839*	*1.597*	*1.435*	*1.186*	*0.826*	*0.486*	*0.244*	*0.191*	*0.19*
Dec	*3.262*	*2.878*	*2.33*	*1.839*	*1.523*	*1.141*	*0.701*	*0.358*	*0.255*	*0.254*
Jan	*4.357*	*3.57*	*3.049*	*2.665*	*2.155*	*1.594*	*0.964*	*0.513*	*0.304*	*0.188*
Feb	*4.371*	*3.677*	*3.094*	*2.836*	*2.382*	*1.85*	*1.375*	*0.939*	*0.496*	*0.399*
Mar	*4.269*	*4.035*	*3.782*	*3.387*	*2.91*	*2.401*	*1.889*	*1.312*	*0.891*	*0.79*
Apr	*3.842*	*3.678*	*3.396*	*3.152*	*2.692*	*2.158*	*1.63*	*1.112*	*0.653*	*0.469*
May	*3.47*	*3.318*	*2.971*	*2.702*	*2.372*	*1.953*	*1.45*	*0.81*	*0.519*	*0.421*
Jun	*2.715*	*2.53*	*2.123*	*1.83*	*1.57*	*1.353*	*0.829*	*0.494*	*0.323*	*0.29*
Jul	*2.138*	*1.818*	*1.427*	*1.24*	*1.025*	*0.904*	*0.596*	*0.281*	*0.153*	*0*
Aug	*1.917*	*1.41*	*1.12*	*0.938*	*0.815*	*0.76*	*0.43*	*0.195*	*0.144*	*0.054*
Sep	*1.7*	*1.388*	*1.09*	*0.922*	*0.745*	*0.634*	*0.334*	*0.157*	*0.084*	*0*

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
B/C Category										
Oct	*2.013*	*1.632*	*1.217*	*1.06*	*0.947*	*0.651*	*0.334*	*0.175*	*0.094*	*0.04*
Nov	*2.096*	*1.757*	*1.523*	*1.385*	*1.128*	*0.77*	*0.416*	*0.224*	*0.176*	*0.176*
Dec	*3.072*	*2.732*	*2.214*	*1.766*	*1.445*	*1.063*	*0.608*	*0.321*	*0.235*	*0.235*
Jan	*4.078*	*3.367*	*2.884*	*2.527*	*2.035*	*1.481*	*0.846*	*0.451*	*0.269*	*0.172*
Feb	*4.128*	*3.478*	*2.917*	*2.666*	*2.238*	*1.715*	*1.225*	*0.802*	*0.449*	*0.371*
Mar	*3.948*	*3.81*	*3.557*	*3.162*	*2.728*	*2.227*	*1.699*	*1.086*	*0.842*	*0.755*
Apr	*3.581*	*3.462*	*3.2*	*2.957*	*2.527*	*1.999*	*1.463*	*0.946*	*0.596*	*0.437*
May	*3.266*	*3.138*	*2.811*	*2.56*	*2.236*	*1.812*	*1.294*	*0.699*	*0.468*	*0.398*
Jun	*2.575*	*2.476*	*2.117*	*1.83*	*1.57*	*1.281*	*0.723*	*0.435*	*0.298*	*0.29*
Jul	*2.138*	*1.818*	*1.427*	*1.24*	*1.025*	*0.904*	*0.514*	*0.255*	*0.13*	*0*
Aug	*1.9*	*1.41*	*1.12*	*0.938*	*0.815*	*0.76*	*0.367*	*0.181*	*0.123*	*0.048*
Sep	*1.632*	*1.388*	*1.09*	*0.922*	*0.745*	*0.634*	*0.265*	*0.152*	*0.067*	*0*
C Category										
Oct	*1.838*	*1.488*	*1.217*	*1.06*	*0.853*	*0.566*	*0.249*	*0.156*	*0.071*	*0.034*
Nov	*1.91*	*1.6*	*1.389*	*1.307*	*1.012*	*0.673*	*0.315*	*0.197*	*0.162*	*0.162*
Dec	*2.769*	*2.461*	*2.002*	*1.651*	*1.295*	*0.93*	*0.471*	*0.276*	*0.217*	*0.217*
Jan	*3.656*	*3.004*	*2.581*	*2.308*	*1.816*	*1.296*	*0.671*	*0.38*	*0.232*	*0.158*
Feb	*3.722*	*3.112*	*2.593*	*2.398*	*1.992*	*1.501*	*0.999*	*0.653*	*0.406*	*0.342*
Mar	*3.504*	*3.372*	*3.133*	*2.832*	*2.422*	*1.956*	*1.381*	*0.89*	*0.784*	*0.711*
Apr	*3.192*	*3.078*	*2.839*	*2.648*	*2.246*	*1.75*	*1.208*	*0.776*	*0.546*	*0.404*
May	*2.928*	*2.81*	*2.519*	*2.337*	*1.993*	*1.587*	*1.055*	*0.58*	*0.421*	*0.374*
Jun	*2.328*	*2.236*	*1.962*	*1.83*	*1.553*	*1.121*	*0.567*	*0.364*	*0.276*	*0.275*
Jul	*1.991*	*1.818*	*1.427*	*1.24*	*1.025*	*0.845*	*0.394*	*0.222*	*0.103*	*0*
Aug	*1.738*	*1.41*	*1.12*	*0.938*	*0.815*	*0.681*	*0.275*	*0.162*	*0.097*	*0.042*
Sep	*1.496*	*1.366*	*1.09*	*0.922*	*0.745*	*0.576*	*0.182*	*0.138*	*0.043*	*0*
C/D Category										
Oct	*1.663*	*1.348*	*1.169*	*1.057*	*0.755*	*0.468*	*0.193*	*0.134*	*0.051*	*0.029*
Nov	*1.724*	*1.448*	*1.293*	*1.214*	*0.899*	*0.561*	*0.245*	*0.17*	*0.149*	*0.148*
Dec	*2.472*	*2.207*	*1.843*	*1.523*	*1.147*	*0.779*	*0.369*	*0.241*	*0.199*	*0.198*
Jan	*3.246*	*2.671*	*2.34*	*2.086*	*1.603*	*1.093*	*0.527*	*0.332*	*0.2*	*0.144*
Feb	*3.328*	*2.774*	*2.328*	*2.139*	*1.751*	*1.272*	*0.792*	*0.58*	*0.365*	*0.314*
Mar	*3.078*	*2.978*	*2.794*	*2.506*	*2.13*	*1.662*	*1.064*	*0.827*	*0.725*	*0.655*
Apr	*2.821*	*2.728*	*2.542*	*2.353*	*1.972*	*1.485*	*0.962*	*0.699*	*0.497*	*0.371*
May	*2.607*	*2.507*	*2.287*	*2.112*	*1.756*	*1.343*	*0.835*	*0.514*	*0.378*	*0.351*
Jun	*2.09*	*2.008*	*1.82*	*1.725*	*1.376*	*0.943*	*0.445*	*0.318*	*0.252*	*0.252*
Jul	*1.799*	*1.662*	*1.427*	*1.24*	*1.025*	*0.707*	*0.307*	*0.192*	*0.08*	*0*
Aug	*1.574*	*1.41*	*1.12*	*0.938*	*0.815*	*0.568*	*0.213*	*0.14*	*0.074*	*0.038*
Sep	*1.358*	*1.234*	*1.09*	*0.922*	*0.735*	*0.455*	*0.168*	*0.111*	*0.027*	*0*
D Category										
Oct	*1.495*	*1.235*	*1.105*	*0.963*	*0.663*	*0.362*	*0.165*	*0.108*	*0.037*	*0.024*
Nov	*1.549*	*1.325*	*1.223*	*1.088*	*0.791*	*0.435*	*0.208*	*0.141*	*0.134*	*0.133*
Dec	*2.209*	*1.996*	*1.714*	*1.36*	*1.006*	*0.608*	*0.308*	*0.205*	*0.18*	*0.18*
Jan	*2.892*	*2.39*	*2.125*	*1.845*	*1.393*	*0.865*	*0.436*	*0.29*	*0.18*	*0.13*
Feb	*2.971*	*2.476*	*2.082*	*1.878*	*1.51*	*1.017*	*0.646*	*0.529*	*0.328*	*0.286*
Mar	*2.727*	*2.632*	*2.456*	*2.195*	*1.839*	*1.318*	*0.88*	*0.764*	*0.667*	*0.6*
Apr	*2.506*	*2.427*	*2.265*	*2.061*	*1.696*	*1.192*	*0.779*	*0.641*	*0.452*	*0.337*
May	*2.326*	*2.252*	*2.084*	*1.867*	*1.521*	*1.071*	*0.679*	*0.462*	*0.339*	*0.323*

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Jun	*1.875*	*1.821*	*1.679*	*1.535*	*1.2*	*0.743*	*0.371*	*0.278*	*0.231*	*0.229*
Jul	*1.616*	*1.517*	*1.427*	*1.24*	*0.96*	*0.551*	*0.258*	*0.161*	*0.063*	*0*
Aug	*1.417*	*1.332*	*1.12*	*0.938*	*0.763*	*0.44*	*0.181*	*0.113*	*0.058*	*0.033*
Sep	*1.22*	*1.137*	*1.074*	*0.877*	*0.659*	*0.327*	*0.158*	*0.084*	*0.021*	*0*
Category Total Flow Assurance curves (mill. m^3)										
A Category										
Oct	*3.624*	*1.882*	*1.217*	*1.06*	*0.96*	*0.838*	*0.726*	*0.362*	*0.151*	*0.069*
Nov	*6.117*	*3.836*	*2.661*	*2.22*	*1.715*	*1.504*	*1.185*	*0.692*	*0.245*	*0.226*
Dec	*9.947*	*7.842*	*5.733*	*4.051*	*3.122*	*2.596*	*1.69*	*1.076*	*0.327*	*0.293*
Jan	*12.56*	*9.689*	*7.259*	*5.444*	*4.157*	*3.446*	*2.49*	*1.407*	*0.423*	*0.234*
Feb	*12.09*	*9.486*	*7.167*	*5.56*	*4.364*	*3.665*	*2.891*	*1.938*	*0.695*	*0.465*
Mar	*11.343*	*9.423*	*7.562*	*5.921*	*4.771*	*4.116*	*3.322*	*2.391*	*1.264*	*0.862*
Apr	*7.502*	*6.516*	*5.416*	*4.553*	*3.759*	*3.128*	*2.478*	*1.768*	*0.913*	*0.566*
May	*4.832*	*4.418*	*3.766*	*3.272*	*2.74*	*2.244*	*1.896*	*1.132*	*0.718*	*0.429*
Jun	*2.906*	*2.53*	*2.123*	*1.83*	*1.57*	*1.37*	*1.032*	*0.624*	*0.375*	*0.29*
Jul	*2.138*	*1.818*	*1.427*	*1.24*	*1.025*	*0.904*	*0.756*	*0.347*	*0.206*	*0*
Aug	*1.917*	*1.41*	*1.12*	*0.938*	*0.815*	*0.76*	*0.555*	*0.236*	*0.193*	*0.072*
Sep	*1.796*	*1.388*	*1.09*	*0.922*	*0.745*	*0.634*	*0.473*	*0.169*	*0.118*	*0*
A/B Category										
Oct	*3.469*	*1.882*	*1.217*	*1.06*	*0.96*	*0.838*	*0.674*	*0.331*	*0.133*	*0.057*
Nov	*5.965*	*3.836*	*2.661*	*2.22*	*1.715*	*1.504*	*1.18*	*0.637*	*0.214*	*0.207*
Dec	*9.375*	*7.39*	*5.437*	*3.87*	*2.968*	*2.487*	*1.69*	*0.99*	*0.285*	*0.274*
Jan	*11.797*	*9.071*	*6.829*	*5.163*	*3.931*	*3.235*	*2.301*	*1.291*	*0.363*	*0.204*
Feb	*11.403*	*8.9*	*6.705*	*5.245*	*4.103*	*3.436*	*2.679*	*1.759*	*0.588*	*0.426*
Mar	*10.583*	*8.761*	*7.005*	*5.571*	*4.468*	*3.853*	*3.082*	*2.13*	*1.036*	*0.825*
Apr	*6.997*	*6.065*	*5.045*	*4.289*	*3.527*	*2.927*	*2.283*	*1.574*	*0.768*	*0.503*
May	*4.532*	*4.15*	*3.549*	*3.118*	*2.7*	*2.244*	*1.739*	*1.009*	*0.609*	*0.429*
Jun	*2.874*	*2.53*	*2.123*	*1.83*	*1.57*	*1.37*	*0.932*	*0.558*	*0.345*	*0.29*
Jul	*2.138*	*1.818*	*1.427*	*1.24*	*1.025*	*0.904*	*0.678*	*0.31*	*0.179*	*0*
Aug	*1.917*	*1.41*	*1.12*	*0.938*	*0.815*	*0.76*	*0.494*	*0.212*	*0.168*	*0.062*
Sep	*1.751*	*1.388*	*1.09*	*0.922*	*0.745*	*0.634*	*0.404*	*0.163*	*0.101*	*0*
B Category										
Oct	*3.31*	*1.882*	*1.217*	*1.06*	*0.96*	*0.838*	*0.601*	*0.307*	*0.114*	*0.047*
Nov	*5.651*	*3.836*	*2.661*	*2.22*	*1.715*	*1.504*	*1.079*	*0.59*	*0.196*	*0.19*
Dec	*8.805*	*6.938*	*5.132*	*3.668*	*2.811*	*2.329*	*1.652*	*0.912*	*0.263*	*0.254*
Jan	*11.041*	*8.467*	*6.429*	*4.871*	*3.708*	*3.026*	*2.111*	*1.181*	*0.313*	*0.188*
Feb	*10.714*	*8.324*	*6.301*	*4.93*	*3.855*	*3.21*	*2.463*	*1.574*	*0.504*	*0.399*
Mar	*9.829*	*8.108*	*6.594*	*5.223*	*4.202*	*3.593*	*2.843*	*1.868*	*0.899*	*0.79*
Apr	*6.506*	*5.629*	*4.742*	*4.031*	*3.311*	*2.729*	*2.087*	*1.378*	*0.656*	*0.469*
May	*4.229*	*3.874*	*3.354*	*2.952*	*2.549*	*2.115*	*1.58*	*0.886*	*0.52*	*0.421*
Jun	*2.715*	*2.53*	*2.123*	*1.83*	*1.57*	*1.353*	*0.829*	*0.494*	*0.323*	*0.29*
Jul	*2.138*	*1.818*	*1.427*	*1.24*	*1.025*	*0.904*	*0.596*	*0.281*	*0.153*	*0*
Aug	*1.917*	*1.41*	*1.12*	*0.938*	*0.815*	*0.76*	*0.43*	*0.195*	*0.144*	*0.054*
Sep	*1.7*	*1.388*	*1.09*	*0.922*	*0.745*	*0.634*	*0.334*	*0.157*	*0.084*	*0*
B/C Category										
Oct	*3.139*	*1.882*	*1.217*	*1.06*	*0.96*	*0.838*	*0.528*	*0.287*	*0.096*	*0.04*
Nov	*5.325*	*3.836*	*2.661*	*2.22*	*1.715*	*1.462*	*0.97*	*0.547*	*0.181*	*0.176*
Dec	*8.255*	*6.529*	*4.835*	*3.476*	*2.65*	*2.174*	*1.497*	*0.839*	*0.242*	*0.235*

Columns are FDC percentage points:										
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**99**
Jan	*10.329*	*7.947*	*6.044*	*4.59*	*3.487*	*2.821*	*1.919*	*1.077*	*0.278*	*0.172*
Feb	*10.06*	*7.824*	*5.917*	*4.624*	*3.616*	*2.986*	*2.243*	*1.395*	*0.457*	*0.371*
Mar	*9.147*	*7.619*	*6.186*	*4.878*	*3.936*	*3.341*	*2.591*	*1.606*	*0.849*	*0.755*
Apr	*6.072*	*5.287*	*4.459*	*3.779*	*3.106*	*2.533*	*1.891*	*1.196*	*0.599*	*0.437*
May	*3.976*	*3.658*	*3.17*	*2.794*	*2.401*	*1.964*	*1.416*	*0.77*	*0.469*	*0.398*
Jun	*2.575*	*2.476*	*2.117*	*1.83*	*1.57*	*1.281*	*0.723*	*0.435*	*0.298*	*0.29*
Jul	*2.138*	*1.818*	*1.427*	*1.24*	*1.025*	*0.904*	*0.514*	*0.255*	*0.13*	*0*
Aug	*1.9*	*1.41*	*1.12*	*0.938*	*0.815*	*0.76*	*0.367*	*0.181*	*0.123*	*0.048*
Sep	*1.632*	*1.388*	*1.09*	*0.922*	*0.745*	*0.634*	*0.265*	*0.152*	*0.067*	*0*
C Category										
Oct	*2.888*	*1.882*	*1.217*	*1.06*	*0.96*	*0.791*	*0.429*	*0.261*	*0.072*	*0.034*
Nov	*4.919*	*3.805*	*2.661*	*2.22*	*1.697*	*1.318*	*0.832*	*0.498*	*0.167*	*0.162*
Dec	*7.599*	*6*	*4.445*	*3.246*	*2.417*	*1.965*	*1.3*	*0.759*	*0.223*	*0.217*
Jan	*9.481*	*7.272*	*5.527*	*4.23*	*3.17*	*2.545*	*1.67*	*0.962*	*0.24*	*0.158*
Feb	*9.251*	*7.163*	*5.389*	*4.222*	*3.276*	*2.686*	*1.948*	*1.206*	*0.413*	*0.342*
Mar	*8.35*	*6.922*	*5.583*	*4.431*	*3.548*	*2.994*	*2.213*	*1.375*	*0.79*	*0.711*
Apr	*5.514*	*4.779*	*4.013*	*3.414*	*2.786*	*2.248*	*1.606*	*1.008*	*0.549*	*0.404*
May	*3.59*	*3.295*	*2.853*	*2.555*	*2.147*	*1.728*	*1.169*	*0.646*	*0.422*	*0.374*
Jun	*2.328*	*2.236*	*1.962*	*1.83*	*1.553*	*1.121*	*0.567*	*0.364*	*0.276*	*0.275*
Jul	*1.991*	*1.818*	*1.427*	*1.24*	*1.025*	*0.845*	*0.394*	*0.222*	*0.103*	*0*
Aug	*1.738*	*1.41*	*1.12*	*0.938*	*0.815*	*0.681*	*0.275*	*0.162*	*0.097*	*0.042*
Sep	*1.496*	*1.366*	*1.09*	*0.922*	*0.745*	*0.576*	*0.182*	*0.138*	*0.043*	*0*
C/D Category										
Oct	*2.637*	*1.882*	*1.217*	*1.06*	*0.96*	*0.677*	*0.36*	*0.232*	*0.052*	*0.029*
Nov	*4.518*	*3.494*	*2.661*	*2.136*	*1.548*	*1.16*	*0.724*	*0.45*	*0.152*	*0.148*
Dec	*6.957*	*5.492*	*4.11*	*3.003*	*2.189*	*1.74*	*1.138*	*0.689*	*0.205*	*0.198*
Jan	*8.654*	*6.633*	*5.075*	*3.871*	*2.859*	*2.252*	*1.455*	*0.873*	*0.208*	*0.144*
Feb	*8.46*	*6.534*	*4.922*	*3.833*	*2.943*	*2.371*	*1.672*	*1.093*	*0.372*	*0.314*
Mar	*7.577*	*6.274*	*5.069*	*3.991*	*3.175*	*2.626*	*1.836*	*1.277*	*0.731*	*0.655*
Apr	*4.976*	*4.307*	*3.632*	*3.064*	*2.473*	*1.947*	*1.332*	*0.914*	*0.5*	*0.371*
May	*3.221*	*2.957*	*2.598*	*2.315*	*1.898*	*1.474*	*0.94*	*0.575*	*0.379*	*0.351*
Jun	*2.09*	*2.008*	*1.82*	*1.725*	*1.376*	*0.943*	*0.445*	*0.318*	*0.252*	*0.252*
Jul	*1.799*	*1.662*	*1.427*	*1.24*	*1.025*	*0.707*	*0.307*	*0.192*	*0.08*	*0*
Aug	*1.574*	*1.41*	*1.12*	*0.938*	*0.815*	*0.568*	*0.213*	*0.14*	*0.074*	*0.038*
Sep	*1.358*	*1.234*	*1.09*	*0.922*	*0.735*	*0.455*	*0.168*	*0.111*	*0.027*	*0*
D Category										
Oct	*2.396*	*1.862*	*1.217*	*1.06*	*0.872*	*0.555*	*0.32*	*0.198*	*0.038*	*0.024*
Nov	*4.13*	*3.216*	*2.529*	*1.94*	*1.391*	*0.988*	*0.651*	*0.399*	*0.137*	*0.133*
Dec	*6.353*	*5.032*	*3.809*	*2.728*	*1.968*	*1.497*	*1.02*	*0.62*	*0.186*	*0.18*
Jan	*7.889*	*6.051*	*4.652*	*3.494*	*2.554*	*1.936*	*1.294*	*0.79*	*0.187*	*0.13*
Feb	*7.714*	*5.951*	*4.48*	*3.444*	*2.612*	*2.033*	*1.46*	*1.003*	*0.335*	*0.286*
Mar	*6.885*	*5.677*	*4.559*	*3.567*	*2.805*	*2.209*	*1.593*	*1.18*	*0.672*	*0.6*
Apr	*4.497*	*3.886*	*3.272*	*2.719*	*2.159*	*1.619*	*1.121*	*0.841*	*0.455*	*0.337*
May	*2.894*	*2.668*	*2.37*	*2.054*	*1.653*	*1.193*	*0.777*	*0.519*	*0.34*	*0.323*
Jun	*1.875*	*1.821*	*1.679*	*1.535*	*1.2*	*0.743*	*0.371*	*0.278*	*0.231*	*0.229*
Jul	*1.616*	*1.517*	*1.427*	*1.24*	*0.96*	*0.551*	*0.258*	*0.161*	*0.063*	*0*
Aug	*1.417*	*1.332*	*1.12*	*0.938*	*0.763*	*0.44*	*0.181*	*0.113*	*0.058*	*0.033*
Sep	*1.22*	*1.137*	*1.074*	*0.877*	*0.659*	*0.327*	*0.158*	*0.084*	*0.021*	*0*

17 APPENDIX D: REPORT COMMENTS

Page / Section	Report statement	Comments	Changes made?	Author comment
Comments received from T Nyamande: 24 Feb 2014				
		Add glossary page - indicating key terms and definitions	*No*	*These are technical reports with no new Reserve terms and definitions included. It is a major task to set this up and get agreement on the terms that require this. Definitions should be referenced etc. Also, this should have appeared from day one in the reports. It is suggested that such a glossary be set up by DWA (as the abbreviations list) as part of the mentoring and then can be added to and used during all stakeholder meetings etc.*
		Please check if the Regulations Steps are synchronized with the ones on the procedures for RQOs.	*No*	*Yes - as stipulated in Table in inception report which indications all the Regulations (steps) for each of the three processes and how they fit into the integrated steps. RQOs are not part of this report, but when we get to that, we will illustrate this in detail.*
		There is a need to incorporate NFEPAS in the EWR report to indicate whether NFEPAS agree with the pes	*Yes*	*See 3.1 and 7.1. Only two sites are in possible NFEPAs. Both are confirmed as not being NFEPAs.*
Comments received from M Thwala: 24 Feb 2014				
Executive summary		*The Integrated Steps table, step 2 of WRCS doesn't seem to be incorporated or it is not clear to me at what stage is "linking value and condition" done.*	*No*	*This step in the Fig 3.1 (Inception report) forms part of the visioning step which forms part of the integrated step 2 (stakeholder process). However, in hindsight and as indicated in the evaluation of the WRCS guidelines done as part of the Vaal study, this is an extremely vague step and these links are prevalent in many steps, specifically probably in the MC steps as that is where value and condition (EC) are integrated.*
Executive		*DWA, 2013a and DWA, 2013b are not in the reference list, is it because the*	*No*	*They are in the reference list of the main report. It is possible that you checked one of*

Page / Section	Report statement	Comments	Changes made?	Author comment
summary		*documents are listed in the Document Index or because they are not yet signed off?*		*the appendices' reference lists by mistake.*
Executive summary		*MG_R_EWR4: Msunduze River Ecoclassification Results: how is it that the PES and REC are B/C in the Executive Summary (can they even be B/C given the summary of the results) but in Section 11: PES is D/E and REC is D.*	*Yes*	*The tables (with colours) are correct - the accompanying text is a cut and paste error. Has been corrected.*