REPORT NO: 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

PROJECT NUMBER: WP 10679

VOLUME 3: ECOCLASSIFICATION AND EWR ASSESSMENT ON THE MKOMAZI, UMNGENI, AND MVOTI RIVERS

JULY 2014

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

RfA10_2014

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REFERENCE

This report is to be referred to in bibliographies as:

Department of Water and Sanitation, South Africa, July 2014. 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. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd.

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DEPARTMENT OF WATER AND SANITATION

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 3: ECOCLASSIFICATION AND EWR ASSESSMENT ON THE MKOMAZI,uMNGENIAND MVOTI RIVERS

Approved for RFA by:

…………………………………..	…………………………………..
Delana Louw	Date
Project Manager	

DEPARTMENT OF WATER AND SANITATION (DWS)
Approved for DWS 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 and Ecohydrology
- Dr Andrew Deacon: Macro-invertebrates
- Shael Koekemoer: Diatoms
- Dr Pieter Kotze: Fish
- James Mackenzie: Riparian vegetation
- Mark Rountree: Geomorphology
- Dr Patsy Scherman: Water quality

REPORT SCHEDULE

Version	Date
First draft	July 2014
Final Draft	August 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 evaluation of 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 seven of these sites were assessed using a revised and extendedIntermediate Ecological Reserve Methodology.

This report documents the results of the EcoClassification and EWR assessment for these seven sites.

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 sevenIntermediateEWR sites are described in DWA (2013b) and listed below.

Table 1: EWR sites (Intermediate level) selected in the study area

EWR site name	SQ[1]	River	Latitude	Longitude	Eco Region (Level II)	Geomorphic Zone	Alt (m)	MRU[2]	Quat[3]
Mv_I_EWR1	U40B-03770	Heinespruit	-29.13054	30.64002	16.02	Lower Foothills	929	MRU Heyns A	U40B
Mv_I_EWR2	U40H-04064	Mvoti	-29.26398	31.03513	17.03	Lower Foothills	203	MRU Mvoti C	U40H
Mg_I_EWR2	U20E-04243	uMngeni	-29.46184	30.29832	16.03	Upper Foothills	725	MRU Mgeni B	U20E
Mg_I_EWR5	U20L-04435	uMngeni	-29.64521	30.74556	17.03	Upper Foothills	177	MRU Mgeni D	U20L
Mk_I_EWR1	U10E-04380	Mkomazi	-29.74338	29.91165	16.03	Lower Foothills	916	MRU Mkomazi B	U20F
Mk_I_EWR2	U10J-04679	Mkomazi	-29.921	30.08448	16.02	Upper Foothills	537	MRU Mkomazi C	U20J
Mk_I_EWR3	U10M-04746	Mkomazi	-30.132	30.66245	17.01	Lower Foothills	50	MRU Mkomazi D	U10M

1 Sub Quaternary reach 2 Management Resource Unit 3 Quaternary catchment

ECOCLASSIFICATION RESULTS

The EcoClassification results are summarised below.

MG_I_EWR2: uMNGENI RIVER

EIS: MODERATE
Highest scoring metrics were diversity of habitat types and migration route. Rare and endangered riparian species occur and intolerant vegetation species are present.

PES: C/D

- Decreased base flows and floods due to Midmar Dam resulting in a loss of flow diversity.
- Alien invasive vegetation, grazing pressure and species composition change in the riparian zone has led to a general loss of connectivity and resulted in bank modification.
- The decrease in baseflows has impacted on habitat availability and abundance.
- Deteriorated water quality impacts (Howick and sediment dam releases has seriously impacted on the fish frequency of occurrence.

REC: C/D
The EIS was moderate and the REC is set to maintain the PES. The fish component is in an unacceptable condition and has to improve to a D EC. This improvement will not require changes in flow.

Component	PES & REC
IHI Hydrology	C/D
Physico chemical	C/D
Geomorphology	D
Fish	E* (D)
Invertebrates	C
Instream	D
Riparian vegetation	C
EcoStatus	C
Instream IHI	D
Riparian IHI	C
EIS	MODERATE
*** Fish to improve**	

MG_I_EWR5: uMNGENI RIVER

- **EIS: MODERATE**
- Highest scoring metrics were diversity of habitat types and features, taxon richness and rare and endangered riparian species.

- **PES: D**
- Decreased baseflows and floods due to upstream dams and general landuse in the upper catchment.
- Reduced habitat abundance.
- Deteriorated water quality (uMnsunduze inflows etc. and increased sedimentation).
- Alien invasive vegetation species, vegetation removal and sand mining leading to a general loss of connectivity and bank modification.
- Presence of two predatory alien fish species in the reach.

- **REC: D**

EIS was Moderate and the REC was therefore set to maintain the PES.

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

MK_I_EWR1: MKOMAZI RIVER

EIS: MODERATE

Highest scoring metrics were unique instream biota, species intolerant to flow, diversity of habitat types and features and rare and endangered riparian species.

PES: C

- Overgrazing and alien invasive vegetation in the riparian zones have led to substrate exposure and increased erosion.
- Increased sedimentation has resulted in higher turbidity.
- Migration barriers and alien fish species.

REC: C

- EIS was Moderate and the REC was therefore to maintain the PES. Due to non-flow related impacts on riparian vegetation, the EWR was set for the instream EC of a B/C.

AEC down: D

- The scenario is based on the impacts of a possible upstream dam which will result in:
- Decreased base flows and floods from a dam.
- Some change in water temperature.
- Erosion of the marginal zone due to scour.
- Decreased fines within the system.
- Increased alien vegetation due to decreased floods.

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

MK_I_EWR2: MKOMAZI RIVER

EIS: HIGH
Highest scoring metrics were unique instream biota, species intolerant to flow, diversity of habitat types, migration route, rare and endangered riparian species, riparian species intolerant to flow and migration corridor for birds.

PES: B
- Increased catchment erosion and alien invasive vegetation in the upper riparian zone leading to substrate exposure.
- Alien predatory fish species.

REC: B
The EIS was High and although an improvement is normally required most components are already in a B EC except for fish which is impacted by alien species. The REC was therefore set to maintain the PES.

AEC down: C
The scenario is based on the impacts of a possible upstream dam which will result in:

- Decreased base flows and floods.
- Some change in water temperature and decreased turbidity.
- Encroachment of non-woody vegetation and more reeds in the marginal zone.
- Reduced scour resulting in increased sedimentation.
- Less mobile beds.
- Increased alien vegetation due to decreased floods.

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

MK_I_EWR3: MKOMAZI RIVER

EIS: MODERATE
- Highest scoring metrics were unique instream biota, species intolerant to flow, diversity of habitat types and features and rare and endangered riparian species.

PES: C
- Overgrazing, trampling and alien invasive vegetation impact the riparian zone and has resulted in substrate exposure and increased erosion.
- The structural changes in vegetation impact on longitudinal and lateral connectivity

REC: C
- The EIS was Moderate and the REC was therefore set to maintain the PES. Due to non-flow related impacts on riparian vegetation, the EWR was set for the instream EC of a B.

AEC down: D
- The scenario is based on the impacts of a possible upstream dam which will result in:
- Decreased base flows and large floods.
- More islands, fewer secondary channels and less quality instream habitats.
- Increased woody vegetation on islands.
- Loss of non-woody vegetation as it will be out-shaded by the increased woody vegetation.
- Increased marginal vegetation encroachment.

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

MV_I_EWR1: HEYNESPRUIT

EIS: MODERATE
Unique fish occur (*B. natalensis* – regional endemic) and instream habitat sensitive to flow changes. Rare and endangered riparian species are present and are intolerant.

PES: C
- Decreased base flows impact to some extent on habitat availability and abundance.
- Deteriorated water quality due to releases from the WWTW resulting in high nutrient levels as well as the presence of toxics.
- High occurrence of alien vegetation species and the presence of three predatory alien fish species.
- General loss of connectivity and bank modification.

REC: C
The EIS was Moderate and therefore the REC was set to maintain the PES.

AEC down: D
- The scenario included further decreased baseflows and floods:
- Increased sedimentation of riffles and fine accumulation in pools.
- Vegetation species composition change with a higher occurrence of grasses and shrubs, and a decrease in sedges.
- Increased nutrients.

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

MV_I_EWR2 MVOTI RIVER

EIS: MODERATE
Unique instream fish biota occur (regional freshwater endemics and estuarine fish). There is a diversity of habitat types and the reach is an important migration route for eels. Rare and endangered riparian species are present.

PES: C
- Decreased base flows have impacted to some extent on habitat availability and abundance.
- Deteriorated water quality.
- Catchment erosion.
- Two predatory alien fish species.
- Alien invasive vegetation in the riparian zones along with wood harvesting and clearance has led to a general loss of connectivity and bank modification.

REC: B
The EIS is Moderate, however the instream component of the EIS is High, and improvement can be achieved by non-flow related measures. The REC will therefore indicate the improvement, but an EWR for improved flows will not be set.

AEC down: D
The scenario is based on the impacts of a possible upstream dam which will result in:
- Increased sedimentation of riffles and fines accumulation in pools.
- Vegetation species composition change with a higher occurrence of grasses and shrubs, and a decrease in sedges.
- Increased nutrients.

Component	PES	REC	AEC↓
IHI Hydrology	B/C		
Physico chemical	C	C	D
Geomorphology	C	C	D
Fish	B/C	B	C
Invertebrates	B/C	B	C/D
Instream	B/C	B	C/D
Riparian vegetation	C/D	C/D	D
EcoStatus	C	B	C/D
Instream IHI	C		
Riparian IHI	C		
EIS	MODERATE		

EWR QUANTIFICATION

The final flow requirements are expressed as a percentage of the Natural Mean Annual Runoff and provided in the Table below.

EWR site	Ecological Category	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
Mv_I_EWR1	PES/REC: C	17.36	7.08	3.16	18.2	1.69	9.7	4.85	27.9
	AEC: D			2.26	13	1.6	9.2	3.85	22.2
Mv_I_EWR2	PES/REC instream: B/C	273.96	168.84	48.3	17.6	19.4	7.1	67.7	24.7
	AEC instream: C/D			33.4	12.2	17.6	6.4	51	18.6
Mk_I_EWR1	PES/REC instream: B/C	683.17	660.72	171.78	25.1	67.31	9.9	239.09	35
	AEC: C/D			88.96	13	57.57	8.4	146.53	21.4
Mk_I_EWR2	PES/REC: B	890.91	838.35	220.59	24.8	94.44	10.6	315.03	35.4
	AEC: C			166.69	18.7	81.6	9.2	248.29	27.9
Mk_I_EWR3	PES/REC instream: B	1068.6	983.23	223.42	20.9	104.6	9.8	328.02	30.7
	AEC: C			151.2	14.2	90.35	8.4	241.55	22.6
Mg_I_EWR2	PES/REC: C/D (RDRM C)	228.19	105.4	33.5	14.7	12.1	5.3	45.6	20
Mg_I_EWR5	PES/REC instream:C/D	583.7	245.3	133.57	22.9	17.03	2.9	150.6	25.8

CONCLUSIONS AND RECOMMENDATIONS

The confidence for all the parameters (Table below) is generally Moderate (yellow) and High (green). The only Low confidence (red) is with Mvoti hydrology and this is linked to the available hydrological model for the Mvoti River which is out of date.

Confidence in the hydraulic modelling results overrides the confidence in the biophysical responses and EWR determination. Although the confidence is generally Moderate and High for the lower uMngeni and Mkomazi Rivers, it is Moderate for the Mvoti and Mg_I_EWR. The lowest confidence evaluation is at the Mv_I_EWR 2 site and this is because all measured flow data used for calibrating the hydraulic model was higher than the low flow EWR determination. Further work to improve the hydraulics would require additional measured calibration at very low flows.

The most effective way of improving confidence is linked to monitoring the ecological status of the river and, if required, improving the hydraulics for low flows at selected sites as part of the monitoring programme. No specific studies to improve any confidences other than the monitoring are therefore recommended. A summary of the confidence in the EcoClassification and EWR scenario determination is provided below.

EWR site	Mv_I_EWR1	Mv_I_EWR2	Mg_I_EWR2	Mg_I_EWR5	Mk_I_EWR1	Mk_I_EWR2	Mk_I_EWR3
Data availability	3	2.8	3	3	3	3	3
Eco-Classification	3.3	3.1	3	3.1	3	3	3
Low flow EWR (biotic responses)	3	4	3.3	5	4.3	4.3	4
High flow EWR (biophysical responses	2.5	2.75	3.5	2.75	3.5	3.75	2.25
Hydrology	2	1.5	3	3	3	3	3
Hydraulics (low)	3	2	2	4	3	3	4
Hydraulics (high)	3	3	4	5	4	5	5

EWR site	Mv_I_ EWR1	Mv_I_ EWR2	Mg_I_ EWR2	Mg_I_ EWR5	Mk_I_ EWR1	Mk_I_ EWR2	Mk_I_ EWR3
Overall low flow EWR confidence	3	2	2	4	3	3	4
Overall high flow EWR confidence	3	2.75	3.5	3	3.5	3.75	2.25

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TERMINOLOGY AND ACRONYMS

AEC	Alternative Ecological Category
ASPT	Average Score Per Taxon
BBM	Building Block Methodology
CD: RDM	Chief Directorate: Resource Directed Measures
CEV	Chronic Effect Value
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
DWS	Department Water Affairs and Sanitation (Name change applicable after May 2014)
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
GAI	Geomorphology Assessment Index
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
NWRCS	National Water Resource Classification System
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
REC	Recommended Ecological Category
RDRM	Revised Desktop Reserve Model
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

WRYM	Water Resource Yield Model
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 and Sanitation (DWS) 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). Several 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 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. EWRs have already been determined on five sites situated on the Lovu, Mtamvuna, Karkloof and uMngeni Riversand are documented in DWA (2014). This report focusses on the the EWR determination at the remaining seven EWR sites.

This report therefore documents the results of the EcoClassification and EWR assessment for these seven sites situated in the uMngeni, Mvoti and Mkomazi Rivers.

1.4 EWR SITES

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

Table 1.2 EWR sites (Intermediate level) selected in the study area

EWR site name	SQ[1]	River	Latitude	Longitude	Eco Region (Level II)	Geomorphic Zone	Alt (m)	MRU[2]	Quat[3]
Mv_I_EWR1	U40B-03770	Heinespruit	-29.13054	30.64002	16.02	Lower Foothills	929	MRU Heyns A	U40B
Mv_I_EWR2	U40H-04064	Mvoti	-29.26398	31.03513	17.03	Lower Foothills	203	MRU Mvoti C	U40H
Mg_I_EWR2	U20E-04243	uMngeni	-29.46184	30.29832	16.03	Upper Foothills	725	MRU Mgeni B	U20E
Mg_I_EWR5	U20L-04435	uMngeni	-29.64521	30.74556	17.03	Upper Foothills	177	MRU Mgeni D	U20L
Mk_I_EWR1	U10E-04380	Mkomazi	-29.74338	29.91165	16.03	Lower Foothills	916	MRU Mkomazi B	U20F
Mk_I_EWR2	U10J-04679	Mkomazi	-29.921	30.08448	16.02	Upper Foothills	537	MRU Mkomazi C	U20J
Mk_I_EWR3	U10M-04746	Mkomazi	-30.132	30.66245	17.01	Lower Foothills	50	MRU Mkomazi D	U10M

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 are summarised in Table 1.3.

Table 1.3 Data and information availability

Data and Information Availability
Hydrology ▪ Heinespruit: Mv_I_EWR1 o Natural hydrology: Was derived from a relatively old hydrological assessment (hydrological calibration was only possible at one gauge in the upper reaches of the Mvoti) and was scaled to obtain representative natural flow at the EWR site. Confidence: 2. o Present Hydrology: The high resolution Water Resource Yield Model (WRYM) 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 2. o There is no reliable gauge near the site. ▪ Mvoti River: Mv_I_EWR2 o Natural hydrology: The hydrology was derived from a relatively old detailed hydrological assessment and was scaled to obtain representative natural flow at the EWR site. Confidence: 2. o Present Day hydrology: The high resolution WRYM 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: 1. o There is no reliable gauge near the site. ▪ uMngeni River: Mg_I_EWR2 o Natural hydrology: Was derived from a detailed hydrological assessment, but was scaled to obtain representative natural flow at the EWR site. Confidence: 3. 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: There is no reliable gauge near the site. However U2H048 is the closest gauge situated just below Midmar Dam and upstream of EWR site (1968 – 2014). ▪ uMngeni River: Mg_I_EWR5 o Natural hydrology: The hydrology was derived from a detailed hydrological assessment, but was scaled to obtain representative natural flow at the EWR site. Confidence: 3. 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: U2H055 upstream of site (1989 – 2013) and U2H002 situated downstream of the EWR site but includes runoff from Mqeku tributary (1928 – 1975). ▪ Mkomazi River: Mk_I_EWR1 o Natural hydrology: The hydrology was derived from a detailed hydrological assessment, but was scaled to obtain representative natural flow at the EWR site. Confidence: 3. 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) and wetlands were disaggregated based on information obtained from the Mkomazi study and catchment area scaling. Confidence 3. o Record period: U2H005 upstream of site (1960 – 2014). ▪ Mkomazi River: Mk_I_EWR2 o Natural hydrology: The hydrology was derived from a detailed hydrological assessment, but was scaled to obtain representative natural flow at the EWR site. Confidence: 3. o Present hydrology: The high resolution WRYM system configuration was refined to include simulation of flows at the EWR site. Catchment developments (forestry, small dams and irrigation water use) and wetlands were disaggregated based on information obtained from the Mkomazi study and catchment area scaling. Confidence 3. o Record period: U1H002 is the closest gauge situated upstream of EWR site but with no usable record as observations were only made for about 2 years (1933 to 1935). ▪ Mkomazi River: Mg_I_EWR3 o Natural hydrology: The hydrology was derived from a detailed hydrological assessment, but was scaled to obtain representative natural flow at the EWR site. Confidence: 3. o Present Hydrology: The high resolution WRYM system configuration was refined to include simulation of flows at the EWR site. Catchment developments (forestry, small dams and irrigation water use) and wetlands were disaggregated based on information obtained from the Mkomazi study and catchment area scaling. Confidence 3. o Record period: U1H009which has a good, but short record (2004 – 2014).

Data and Information Availability
Physico-chemical variables ▪ Heinespruit: Mv_I_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, U4H002Q001 (1977 – 2013), is on the Mvoti River upstream of the Heinespruit confluence, although it is in the same Level II EcoRegion as the EWR site (16.03). Umgeni Water (UW) data for RMV005 (n = 60; 2008 - 2013)was used for the present state assessment and was considered more representative of water quality as it is at the same position as the EWR site. Confidence: 3.5 ▪ Mvoti River: Mv_I_EWR2 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 No site was available in the same Level II EcoRegion. The gauging weir, U4H007Q001 (1977 – 1997) in EcoRegion 17.01, is downstream of the EWR site, which is located in EcoRegion 17.03. The closest Umgeni Water sampling site, RHB001001, is on the Hlimbitwa River upstream of the Mvoti confluence. UW data for RHB001 (n = 57; 2008 - 2013)was used for the present state assessment and was considered more representative of water. Confidence: 2.5 ▪ uMngeni River: Mg_I_EWR2 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 Water quality monitoring points in the area: 1 The gauging weir, U2H001Q001, on the uMngeni River upstream of the EWR site at Howick. 2 The gauging weir, U2H048Q001 on the downstream weir at Midmar Dam which is upstream of Howick town. 3 UW monitoring point on the uMngeni River downstream Merrivale Stream (RMB036 (n = 16; 2010 - 2013)) and upstream of the EWR site. 4 UW monitoring point RMG008 on the uMngeni River @ Mortons Drift downstream of the EWR site (n = 60; 2008 - 2013). o A number of other UW points are also present in the area. Note that although data from U2H001Q01 and the Merrivale UW point were assumed to be most representative of water quality state for the site, U2H001Q01could not be used as data are only available from 1977 - 1995 and the weir is no longer active. Both the DWA and Merrivale sites are just within the adjacent EcoRegion (16.01), and that there is a distance of approximately 6.5 km between the UW point and the EWR site. Mortons Drift is downstream the EWR site and within the same EcoRegion. o UW data for RMG008 (n = 60; 2008 - 2013) and RMB036 (n = 16; 2010 – 2013) were used to represent present state. Confidence: 3 ▪ uMngeni River: Mg_I_EWR5 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 Water quality monitoring points in the area are the following: 1 The gauging weir, U2H055Q001, upstream from the EWR site. 2 The gauging weir, U2H015Q001 downstream from the EWR site. 3 UW monitoring point RMG017 upstream at Inanda Weir. 4 UW monitoring point RMG020 downstream at the Inanda Dam inflow. o All monitoring points are in the same Level II EcoRegion as the EWR site. Although all data were evaluated for use, the upstream DWA and UW sites were used for the analysis. o UW data from RMG017 (n = 17, 2010 - 2013) and U2H055Q01 (n = 477, 1990 - 2013) were used to represent present state. Confidence: 3.5 ▪ Mkomazi River: Mg_I_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 Data from gauging weir situated at the EWR site and UW data was used to represent present state: o U1H005Q01 (n = 442 - 630 (Conductivity); 1990 – 2013); o UW RMK002 (n = 25 - 130; 2008 – 2013. Confidence: 3.5 ▪ Mkomazi River: Mg_I_EWR2 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, U1H001Q001, and UW monitoring point RMK004 (Mkmozi at Josephine Bridge) are the closest water quality monitoring points, although both are downstream of the EWR site.

Data and Information Availability
Note that the data record for the gauging weir is only from 1985 - 1988, while UW data are available from 2009 - 2013. The UW data were therefore used for the assessment: o UW data for RMK004 (n = 10 – 25; 2009 – 2013)were used to represent present state. Confidence: 2.5 ▪ Mkomazi River: Mg_I_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 The gauging weirs, U1H009Q001 and U1H006Q01, are both downstream of the EWR site but evaluated for data as in the same Level II EcoRegion. No UW monitoring points are found in this stretch of river: o Data from gauging weir, U1H006Q01 (n = 390; 747 (Conductivity); 1978– 2013). o Data from gauging weir, U1H009Q01 (n = 13; 2009 – 2013). Confidence: 3.5
Geomorphology ▪ Data collected during site visit (August 2013). ▪ Historical aerial photography were sourced and scaled to enable comparison assessments between the historical aerial photography and historical and contemporary Google Earth satellite imagery. ▪ 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: 4
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
Macro-invertebrates ▪ 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, 2013c). Confidence: 3
Diatoms Diatom samples were taken during June and August 2013 at EWR sites in the Mvoti, uMngeni, Heinespruit and Mkomazi. Mv_I_EWR 1 in the Mvoti and Mk_I_EWR1 and Mk_I_EWR 3 in the Mkomazi 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 uMngeni and MkomaziRiver (GroundTruth Consulting, 2006). 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, 11, 13 and 15: EcoClassification

The EcoClassification results are provided for each EWR site.

Chapter 4, 6, 8, 10, 12, 14 and 16: 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 17: Conclusions and Recommendations

The EcoClassification and EWR scenario results are summarised and recommendations are made.

Chapter 18: References

Report references are listed.

Chapter 19: Appendix A: Water Quality Present State Assessment: Intermediate EWR Sites

This appendix details the approach and results of the water quality assessment undertaken at all the EWR sites.

Chapter 20: Appendix B: Diatoms Results

This appendix details the approach and results of the diatom assessment undertaken at all the EWR sites.

Chapter 21: Appendix C: RDRM Output files

The output files are provided for all EWR sites.

Chapter 22: Appendix D: Report Comments

2 APPROACH

The Intermediate Ecological Reserve Methodology (IERM)(DWAF, 1999) was followed. Due to the historical information and number of hydraulic data collection points, the output of the EWR assessment on the Mkomazi River is the same as if the Comprehensive Ecological Reserve Methodology was followed.Associated with the IERM and the CERM is the EcoClassification process at Level IV. 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).
- Geomorphology Assessment Index (GAI): Rountree and du Preez (in prep).
- 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 4 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).

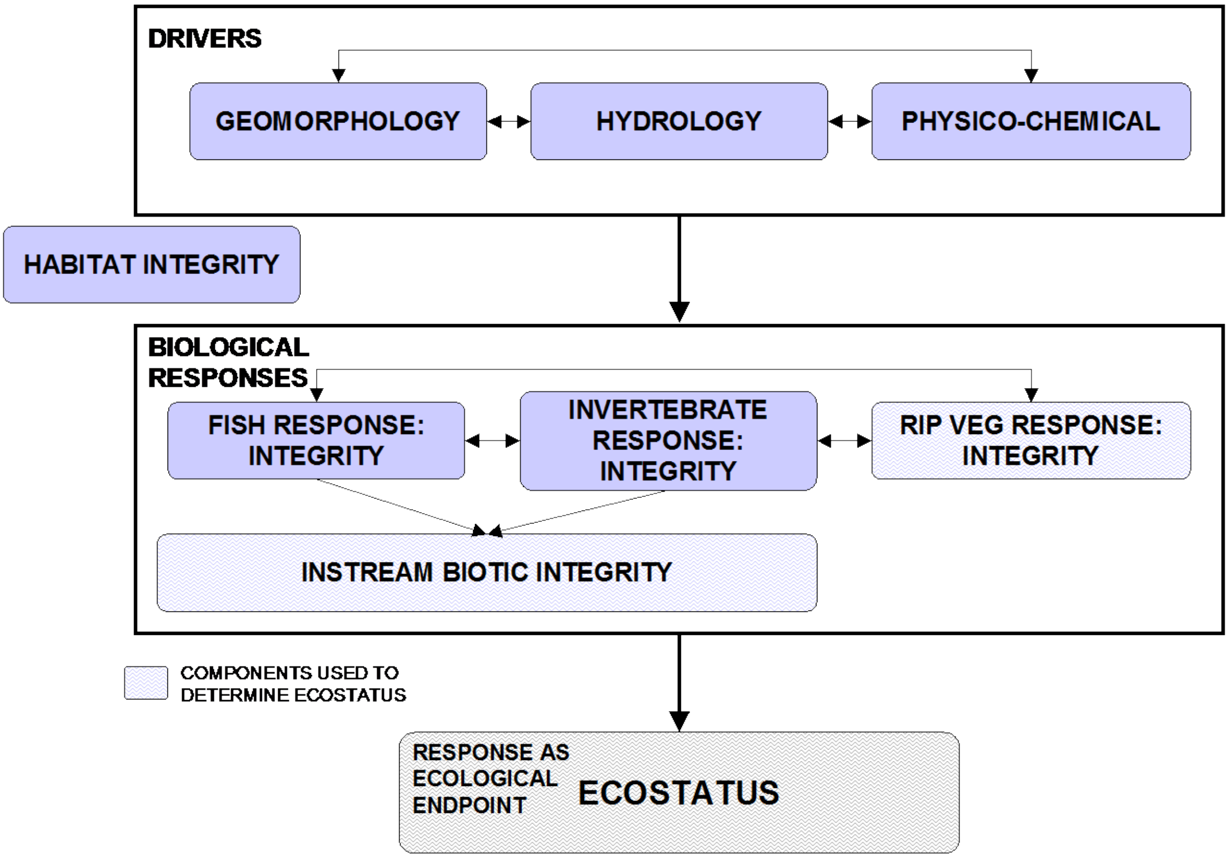

Figure 2.1 EcoStatus Level 4 determination

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.

2.1.3 Recommended Ecological Category

The Recommended Ecological Category (REC) is a recommendation from an ecological viewpoint which is considered within the decision-making process in the National Water Resource Classification System (NWRCS). This recommendation is based on either maintenance of the PES or an improvement there-of. Improvements are only considered if the EIS is HIGH or VERY HIGH.The guidelines to derive the REC based on the level of the PES and the EIS as indicated in Table 2.2. Note that in all cases the restoration potential and practicalities of ecological attainabilityof recommendations that require improvements are considered.

Table 2.2 Guideline for REC determination

PES	EIS	REC	Comment
A, A/B, B	High or Very High	A, A/B, B	The PES will be maintained as it is already in a good condition that will support the high EIS.
B/C	High or Very High	B	As this condition is close to a B, marginal improvement may be required as a B is sufficient to support the high EIS.
C	High or Very High	B	Attempts should be made to improve by a Category.
C/D	High or Very High	B/C	Attempts should be made to improve by a Category.
D	High or Very High	C	Attempts should be made to improve by a Category.
D/E, E, E/F, F	n/a	D	Any Category below a D should (if restoration potential still exists) be improved to at least a D to ensure a minimum level of sustainability. This is irrespective of the EIS. It is unlikely though that it would be practical to improve an F river to a D without considerable investment, effort and possibly physical rehabilitation of the river.

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 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).
- 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).

A stress index is prepared by the fish and invertebrate specialists and these values are used to modify the automated stress index produced using the RDRM.

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.

Stress durations at key points are provided by the fish and invertebrate specialists. 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 and to match the requirements set by specialists.

When the RDRM is used in "desktop" mode, a combination of stress at zero flow and relative weightings for flow (velocity-depth) classes are applied to develop stress-discharge relationships for both the dry and wet seasons. For these intermediate assessments, stress-discharge relationships for the two seasons were supplied by the ecologists and used directly in the RDRM. This effectively bypasses the hydraulic and ecological sub-modules of the RDRM, with these assessments being done externally by ecologists.

The RDRM generated (EWR) flow-durations and stress-durations for the PES categories were then assessed (by ecologists) using the default RDRM "shifts" (relative to natural and taking cognisance of PD), and these were adjusted (based on ecological feedback), if required. Similarly for the AEC, these shifts were modified as necessary following ecological interpretations. In this way, the RDRM is used as a framework for providing EWR results appropriate to an intermediate level of assessment (i.e.,it is not applied merely in "desktop" mode).

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 geomorphological and 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 RDRM 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: HEINESPRUIT (MV_I_EWR1)

3.1 EIS RESULTS

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

- Unique instream biota: *Labeobarbus natalensis* – regional endemic.
- Instream habitat sensitive to flow changes.
- Rare and endangered riparian species: *Crinum bulbispermum* (Declining) and *Gunnera perpensa* (Declining) – both species associated with seep wetlands at the site. The site occurs with an endangered vegetation unit: The Midlands Mistbelt Grassland (Mucina & Rutherford, 2006).
- Refugia and critical riparian habitat: Refugia for above rare and endangered riparian species.
- Intolerant riparian vegetation species.

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 Mv_I_EWR1: Present Ecological State

IHI Hydrology: PES: C
The natural Mean Annual Runoff (nMAR) is 17.36 million cubic meters (MCM) and the Present Day MAR (pMAR) is 7.08 MCM (40.8% of the nMAR). There is a 59% difference in MAR between observed and modeled present hydrology. The town Greytown is located upstream of the EWR site and the discharges from the town's Waste Water Treatment Works (WWTW) enter the river system, affecting both the flow and water quality of the river system. There are a number of small farm dams in tributaries and a relatively large Instream dam (Lake Merthley) near Greytown. The main land use activities in the catchment include extensive forestry and a significant amount of irrigation (sugarcane, maize etc.) also occurs. The baseflow volumes have decreased from natural due to afforestation, urban and irrigation water use. No changes in seasonality and frequency were observed for low flows as well as moderate and large floods, although floods have generally decreased.
Physico-chemical variables: PES: C, Confidence:4
A decline in water quality occurs in the middle reaches (U40H3) with an increase in conductivity and nutrient concentrations. This is due to runoff and return flows from agriculture, urban areas and industrial discharges.The 2012 Green Drop report for WWTW in the study area that potentially impact on rivers, showed a **Medium Risk** rating for the Heinespruit: The water quality Status Quo report (DWA, 2013a) identified SQU40B-03770 where the EWR site is located as a water quality hotspot.The nutrient state of the Heinespruit is very poor, with conditions being substantially worse than the main stem of the river.
Geomorphology: PES: B, Confidence: 4
The geomorphology of the site and the reach of the lower Heinespruit is largely natural. Increased stormwater flows from the upstream town of Greytown may have caused some increased flood peaks, but these could be offset by the impacts of the upstream dam. The morphology of the site is very stable and aerial photographs from 1937 and 1964 confirm a stable channel planform. The coarse bed sediments are largely locally derived dolerite boulders and cobbles, and up and downstream pools have a bedrock base, indicating that sedimentation is not a problem at this site.
IHI Instream: PES: C, Confidence 3   IHI Riparian: PES: C, Confidence 3.7
The instream Index of Habitat Integrity (IHI) is mainly impacted by decreased baseflows. Increased nutrient loading within the system has led to increased algal growth while toxics are present. The biggest impacts on the integrity of the instream riparian area are bank structure and connectivity modification. The presence of alien invasive species in the marginal and non-marginal zone results in structure modification.
Riparian vegetation: PES: B/C, Confidence: 3.3
The marginal zone is narrow (0.5 m) and linear along this small stream. It is dominated by sedges (mainly *Cyperus* and *Juncus* species) and overhanging grasses (*Arundinella napalensis*) or shrubs (*Cliffortia linearifolia*). Marginal zone cover for instream fauna is generally high, with inundated roots, stems and overhanging vegetation. The marginal zone is

close to reference condition but with altered flow favouring sedges. The lower zone is also narrow and dominated by grasses (*A. napalensis*), sedges (*Cyperus* and *Juncus*) and shrubs in places. Some aliens such as *Rubus* and *Ligustrum* occur in patches but cover less than 5% of the sampled area. Flow alteration has favoured shrub and sedge prevalence but remains close to reference expectations. The upper zone is steep and dominated by grasses, both hydrophilic and terrestrial with patches of shrub and isolated clumps of taller woody species in localised areas. Perennial aliens as well as weeds are present, but do not comprise more than 10% of the sub-zone. A fairly large seep wetland is present on the left bank (LB) which is fed predominantly from rainfall and lateral (catenal) seepage. Some flooding from channel flow will also occur but infrequently. The seep wetland is dominated by grasses (such as but not limited to *A. napalensis*) and sedges (such as *Cyperus dives*), with some wetland obligates of note (such as *G. perpensa*).
Fish: PES: C, Confidence: 3
Based on the available fish distribution data and expected habitat composition, six indigenous fish species had a high to definite probability of occurrence under reference conditions. These included the freshwater eel species (*Anguilla mossambica*), two cyprinids (*Labeobarbus natalensis* and *Barbus viviparus*), the Sharptooth catfish(*Clarias gariepinus*) and twocichlids (*Oreochromis mossambicus* and *Tilapia sparrmanii*). 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 slightly tomoderately reduced FROC. The FROC of the eels species were slightly reduced due to reduced base flows resulting in decreased fast habitats (for juveniles). Decrease in base flow also resulted in loss of habitat abundance and availability that decreased the FROC of especially the cyprinids (*Labeobarbus natalensis* and *Barbus viviparus*). The presence and abundance of alien predatory species (*Lepomis macrochirus, Micropterus punctulatus* and *Micropterus salmoides*) impact notably on the abundance and FROC of especially juveniles and adults of the cyprinids and cichlids.
Macro-invertebrates: PES: C, Confidence: 3
A total of 17 SASS5[1] taxa were recorded during the field survey in June 2012 compared to 50 expected under natural conditions. Under these conditions, the SASS score was 102 with an ASPT[2] of 6.0, which reflects a "Fair" condition and is "Moderately modified". The suitability of the river for taxa with a preference for very high flows was low (38% of expected taxa), and for high flows was moderate (56% of expected taxa). These conditions can be attributed to changes in flows due to dams and towns in the catchment. Sensitive taxa included Trichorythidae and Heptageniidae, and taxa expected but not recorded included Perlidae and Hydropsychidae. The suitability of the river for taxa with a preference for Stones-in-Current (SIC) instream habitats was low (38% of expected taxa), and riverine vegetation was even lower (17% of expected taxa). The lower vegetation integrity can be ascribed to changes in species composition. Taxa expected but not recorded included Chlorolestidae and Psephenidae. The suitability of the river for taxa with a high requirement for unmodified physico-chemical conditions were low (33% of expected taxa) while there was an occurrence of 44% of the expected taxa with a preference for moderate water quality. Adverse conditions that might influence the water quality could be sedimentation and increased nutrients. Taxa expected but not recorded included Hydropsychidae, Perlidae, and Psephenidae.

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 decreased base flows that have impacted to some extent on habitat availability and abundance for aquatic biota. Key non-flow related impacts included deteriorated water quality and the presence of alien species. Releases from the WWTW results in high nutrient levels as well as the presence of toxics. There is a high occurrence of alien vegetation species and three predatory alien fish species in the reach. Alien invasive vegetation in the riparian zones has led to a general loss of connectivity and bank modification in the reach.

3.3 RECOMMENDED ECOLOGICAL CATEGORY

The Recommended Ecological Category (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 of a C EC.

3.4 ALTERNATIVE ECOLOGICAL CATEGORY

The scenario included key driver change associated with a hypothetical new upstream dam which would result in:

- Decreased base flows and floods.

- Increased sedimentation of riffles and fine accumulation in pools.
- Vegetation species composition change with a higher occurrence of grasses and shrubs, and a decrease in sedges.
- Increased nutrients.

Each component was adjusted to indicate the metrics that will react to the scenarios. The changes in the rule based models for the Alternative Ecological Category (AEC) are provided electronically and summarised inTable 3.2.

Table 3.2 Mv_I_EWR1: Alternative Ecological Category

Physico-chemical variables: AEC: D
The scenario will result in changes to oxygen and temperature regimes, as well as increases in salts, nutrients and toxics levels. The scenario also describes the sedimentation of riffles, with instream turbidity levels increasing.
Geomorphology: AEC: C
The scenario would result in the overall degradation of instream habitat.
Riparian vegetation: AEC: C/D
Reduced flooding frequency, magnitude and duration will likely favour shrubs along the banks, thus it is expected that woody cover will increase. As long as base flows are not too low and zero flow frequency does not increase shrubs will persist and be able to survive. Reduced base flows will likely favour an increase in non-woody cover in the marginal zone (grasses and sedges) at the expense of open areas. The intensity of this response will depend on the degree to which sediment is accumulated, also a likely response to reduced base flows.
Fish: AEC: D
Reduced base flows will result in reduced abundance of fast habitats with a slight resultant decrease in the FROC of *A. mossambica* (juveniles) and *L. natalensis*. Deterioration of substrate (rocky) due to increased sedimentation and algal growth (increased nutrients) will further decrease the FROC of species with a preference for this habitat feature (*A. mossambica* juveniles and *L. natalensis*. Decreased base flows are also estimated to result in a slight decrease in the habitat availability and suitability of *B. viviparus*, which may result in a slightly deteriorated FROC of this species.
Macro-invertebrates: AEC: D
Four taxa are expected to disappear. Thus a total of 13 SASS5 taxa are expected compared to 50 expected under natural conditions. Under these conditions, the SASS score will be 60 with an ASPT of 4.6, which reflects a "Poor" condition and is "Largely modified". The occurrence of taxa with a preference for very fast flowing water is expected to be reduced from 3 to 2 species out of 8 expected species (38% to 25%), while the taxa with a preference for fast flowing water are expected to be reduced from 5 to 4 species out of 9 expected species (56% to 44%). The overall % change in flow dependence of the species assemblage is 41% which can be attributed to the expected decreased flows due to water abstraction. The occurrence of taxa with a preference for loose cobbles is expected to be reduced from 6 to 3 species out of 16 expected species (38% to 19%). The overall % change in indicators of specific habitat is 44% and is attributed to the sedimentation in the riffle. The occurrence of taxa with a preference for unmodified physico-chemical conditions is affected the worse and is expected to be reduced from 2 to 0 species out of 6 expected species (33% to 0%), while the taxa with a preference for moderate physico-chemical conditions are expected to also be reduced from 2 to 0 species out of 16 expected species (17% to 0%). The overall % change to indicators of modified water quality is a high 61% which is attributed to the change in water temperature and increased nutrients, as well as sedimentation. Taxa with a preference to high flows of good water quality in cobble riffles that are expected to disappear from the system are Trichorythidae, Heptageniidae and Baetidae.

3.5 ECOCLASSIFICATION SUMMARY

The EcoClassification results are summarised in Table 3.3.

Table 3.3 Mv_I_EWR1: Summary of EcoClassification results

Component	PES and REC	AEC↓
IHI Hydrology	C	
Physico chemical	C	D
Geomorphology	B	C
Fish	C	D
Invertebrates	C	D
Instream	C	D
Riparian vegetation	B/C	C/D
EcoStatus	C	D
Instream IHI	C	
Riparian IHI	C	
EIS	MODERATE	

4 EWR REQUIREMENTS: MVOTI RIVER (MV_I_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.

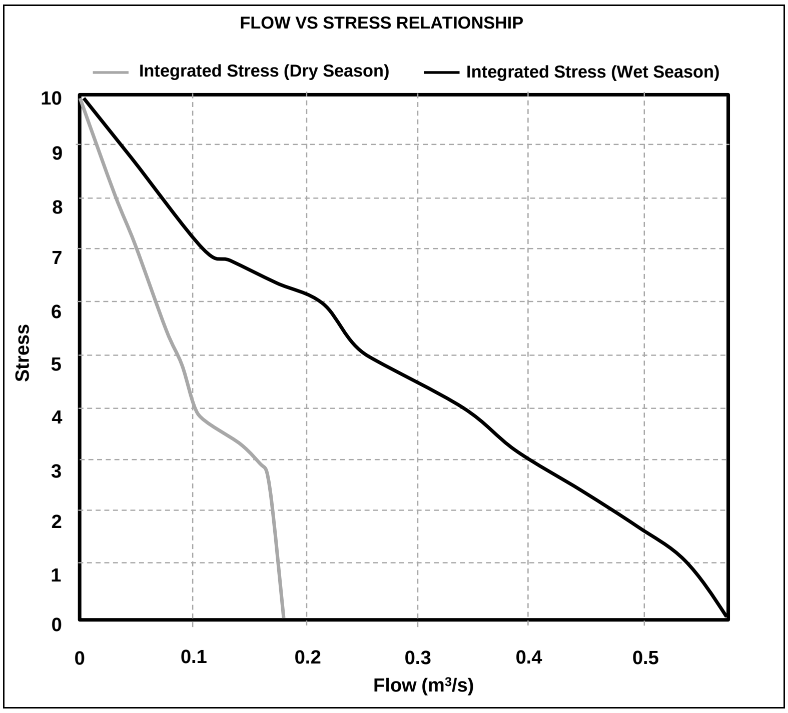

Figure 4.1 Mv_I_EWR1: Stress index

Table 4.1 Mv_I_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	0.17	Adequate fast habitats to ensure limited stress for the indicator species (Perlidae): ▪ 16% Fast Shallow (FS). ▪ 8% Fast Intermediate (FI). ▪ 1% Fast Deep (FD). ▪ 24% Fast over coarse substrate (FCS). ▪ 6% Very fast over coarse substrate (VFCS).	0.54	Habitat very similar to natural conditions with limited stress expected. Critical habitat for indicator species (*L. natalensis*) are as follows: ▪ 21% FS. ▪ 22% FI. ▪ 12% FD.
5	0.08	Although fast habitats are largely reduced it is adequate to maintain biota with moderate stress: ▪ 10%FS. ▪ 2%FI. ▪ 24%FCS. 6%VFCS, but no FD (0%).	0.23	Approximately 50% decrease in critical habitats of indicator species. Habitat composition include approximately: ▪ 15%FS. ▪ 12%FI. ▪ 2%FD.
8	0.01	Limited fast habitats available resulting in high stress: ▪ 1% FS. ▪ 4%FCS. ▪ No FI (0%), FD (0%) and VFCS (0%), resulting in high stress on instream biota.	0.01	Only 1% suitable fast habitats and FI will be lost if exceeded. Very limited breeding habitat and longitudinal connectivity ▪ 1%FS. ▪ 0%FI. ▪ 0%FD.

4.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as March and September. Droughts are set at 90% exceedance (flow) and 10% exceedance (stress). Maintenance flows are set at 40% exceedance (flow) and at 60% exceedance (stress).

4.3 INSTREAM BIOTA REQUIREMENTS

The required stress to maintain the instream PES of a C was determined by specialists and descriptions of key stress points (Table 4.2) are provided below. The requirements are illustrated as flow duration curves in Figure 4.2.

Table 4.2 Mv_I_EWR1: Stress requirements and habitat and instream biota description

PES: C	Dry season		Wet season	
Percentile	Flow (m^3/s)	Description	Flow (m^3/s)	Description
90% (drought)	0.03	Biota will be notably stressed (7) but flow should be adequate to allow survival and ensure maintenance in PES: ▪ 3% FS. ▪ 0% FI. ▪ 0% FD. ▪ 7% FCS. ▪ 0% VFCS.	0.08	Relative high stress (6.8) but adequate fast habitats (abundance and diversity) will be maintained even under drought conditions: ▪ 10% FS. ▪ 2% FI. ▪ 0% FD. ▪ 14% FCS. ▪ 3% VFCS.
70%	0.04	Moderate stress (6) but adequate fast habitats to maintain the biota in PES: ▪ 4% FS. ▪ 0% FI. ▪ 0% FD. ▪ 9% FCS. ▪ 1% VFCS.	0.12	Moderate stress (6.4) but adequate fast habitats to maintain biota (especially for large semi-rheophilic species *L. natalensis*) in healthy state: ▪ 12% FS. ▪ 3.7% FI. ▪ 0% FD. ▪ 21% FCS. ▪ 5% VFCS.

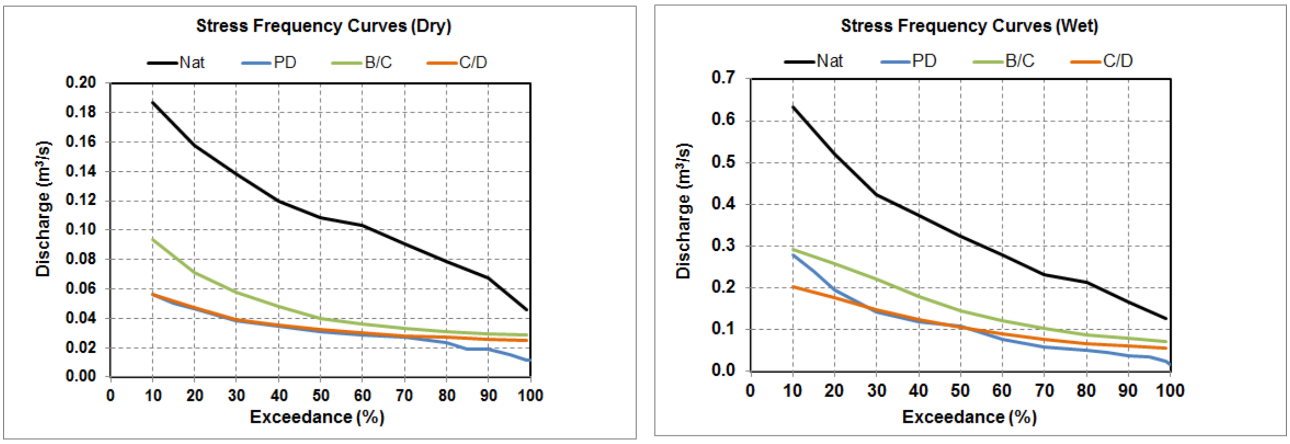

Figure 4.2 Mv_I_EWR1: Flow duration curves for the dry and wet season

4.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

The requested low flows result in some inundation of *Berula erecta* and *C. dives* throughout the year and of *Juncus effasus* for up to 30% of the time in summer. Species such as A*. napalensis* and *Cliffortia linearifolia* receive no inundation, which highlights the importance of high flows for riparian vegetation. It is important to note that there are no zero flows. Together with requested high flows confidence is high that the suggested low flows will maintain the ecological status of the riparian.

4.5 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in Table 4.3 and final high flow results are provided in Table 4.4.

Table 4.3 Mv_I_EWR1: Identification of instream functions addressed by the identified floods for riparian vegetation

Flood Class Flood Range (Peak in m^3/s)	Geomorphology and Riparian vegetation motivation	Fish flood functions						Macro-invertebrate 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)	**Geomorphology:** This small flood flushes fines from the riffle and runs of the active channel. **Riparian vegetation:** This event floods the marginal zone sedges (*C. dives* and *J. effasus*) to above root and lower stem parts and completely inundates macrophytes such as*B. erecta*. It also activates the lower limit of the shrub zone (such as *Cliffortia*). It is required mainly to maintain diversity in the marginal zone and facilitate recruitment in the upper zone.	√	√	√	√	√	√	√	√	√	√
CLASS II (10 - 25)	**Geomorphology:** This large flood is expected to inundate the bar, activate gravels and scour the riffle as well as flush the pools up and downstream of the site. **Riparian vegetation:** This event completely floods the marginal zone inundates upper zone shrubs. It is important for the scouring of the marginal zone, maintaining habitat and species diversity, and provides recruiting opportunities for shrubs in the upper zone. At the same time it also prevents the encroachment of shrubs and terrestrial species to lower areas in the riparian zone.	√	√	√	√	√	√	√	√	√	√

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

Table 4.4 Mv_I_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)	4	Dec to Apr	1.5	2
CLASS II(10 - 25)	1:3	Feb to Mar	10	5

*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 4.5) and an EWR rule (Table 4.6; 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 4.5 Mv_I_EWR1: EWR table for PES and REC: C

Month	Low Flows		High Flows (m^3/s)	
	Drought (90%) (m^3/s)	60% (m^3/s)	Daily average (m^3/s)	Duration (days)
Oct	0.03	0.04		
Nov	0.04	0.04		
Dec	0.04	0.06	1.5	2
Jan	0.05	0.07	1.5	2
Feb	0.07	0.09	10	5
Mar	0.08	0.12	1.5	2
Apr	0.08	0.11	1.5	2
May	0.08	0.10		
Jun	0.06	0.08		
Jul	0.05	0.05		
Aug	0.04	0.04		
Sep	0.03	0.04		

Table 4.6 Mv_I_EWR1: Assurance rules (m^3/s)for PES and REC: C

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.10	0.08	0.06	0.05	0.04	0.04	0.04	0.03	0.03	0.03
Nov	0.12	0.09	0.07	0.06	0.05	0.04	0.04	0.04	0.04	0.03
Dec	0.20	0.14	0.10	0.08	0.07	0.06	0.05	0.05	0.04	0.04
Jan	0.29	0.18	0.14	0.11	0.08	0.07	0.07	0.06	0.05	0.05
Feb	0.32	0.25	0.20	0.15	0.12	0.09	0.09	0.07	0.07	0.06
Mar	0.29	0.26	0.22	0.18	0.15	0.12	0.10	0.09	0.08	0.07
Apr	0.26	0.23	0.20	0.16	0.13	0.11	0.10	0.09	0.08	0.08
May	0.21	0.18	0.16	0.13	0.11	0.10	0.10	0.08	0.08	0.07
Jun	0.17	0.14	0.12	0.10	0.09	0.08	0.07	0.07	0.06	0.06
Jul	0.13	0.11	0.09	0.07	0.06	0.05	0.05	0.05	0.05	0.05
Aug	0.11	0.08	0.07	0.06	0.05	0.04	0.04	0.04	0.04	0.04
Sep	0.10	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.03

Table 4.7 Mv_I_EWR1: Assurance rules (m^3/s)for AEC down: D

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.06	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03
Nov	0.07	0.06	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.03
Dec	0.13	0.09	0.07	0.06	0.05	0.05	0.04	0.04	0.04	0.03
Jan	0.19	0.12	0.10	0.08	0.06	0.06	0.05	0.05	0.04	0.04
Feb	0.21	0.17	0.14	0.11	0.09	0.07	0.07	0.06	0.05	0.05
Mar	0.20	0.18	0.15	0.12	0.10	0.09	0.08	0.07	0.06	0.06
Apr	0.18	0.15	0.13	0.11	0.09	0.09	0.08	0.07	0.07	0.07
May	0.14	0.12	0.11	0.09	0.08	0.08	0.08	0.06	0.06	0.06
Jun	0.10	0.10	0.08	0.07	0.07	0.06	0.06	0.05	0.05	0.05
Jul	0.08	0.07	0.06	0.05	0.05	0.04	0.04	0.04	0.04	0.04
Aug	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.03
Sep	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03

Table 4.8 Mv_I_EWR1: Summary of results as a percentage of the nMAR

EcoStatus	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
PES/REC:C	17.36	7.08	3.16	18.2	1.69	9.7	4.85	27.9
AEC: D			2.26	13	1.6	9.2	3.85	22.2

5 ECOCLASSIFICATION: MVOTI RIVER (MV_I_EWR2)

5.1 EIS RESULTS

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

- Unique instream biota: *L. natalensis*, *B. gurneyi (*regional endemics) and *Acanthopagrus berda*.
- Species/taxon richness: Macro-invertebrates.
- Diversity of habitat types and features: Riffles, pools, overhanging vegetation and islands.
- Migration route: Important for the migration of eel species in the system.
- Rare and Endangered riparian species found in the area: *Crinum macowanii* (Declining); *G. perpensa* (Declining); *Hydrostachyspolymorpha* (Vulnerable).

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 Mv_I_EWR2: Present Ecological State

IHI Hydrology: PES: B/C
The nMAR is 273.96 MCM and the pMAR is 168.84 MCM (61.6% of the nMAR). There is a 38% difference in MAR between observed and modeled present hydrology. The storage regulation in the catchment upstream of the EWR site is low and the only dams in the area include a number of small farm dams in tributaries and a few instream dams with Lake Merthley being the largest. The main land use activities in the catchment include forestry, irrigation and sugarcane (dryland and irrigated). The 1996 hydrological assessment indicated that afforestation has shown a gradual increase over time and the number of farm dams has increased since the late 1970's. The base flows have decreased in volume due to aforementioned land use, while floods have generally decreased although seasonality has remained unchanged.
Physico-chemical variables: PES: C, Confidence:3.5
The water quality Status Quo report (DWA, 2013a)for the study identified the SQ where the EWR site is located, i.e. U40H-04064, as a water quality hotspot. Drivers are elevated nutrient and toxics levels due to discharges from agricultural return flows, and upstream urban and industrial inputs.
Geomorphology: PES: C, Confidence: 3.5
The geomorphology of the site and the reach of the lower Mvoti River have been impacted by small flow reductions associated with farm dams, but the main impact has been the greatly increased sediment yields from the middle and lower catchment. Sediment loads have been increased as a result of small scale/subsistence agriculture, the development of peri-urban (rural) areas, as well as commercial agriculture and forestry. The upstream Hlimbitwa tributary introduces large volumes of sediment to the mainstem channel, and reports from the earlier IFR study indicated that the site was aggrading due to high sediment inputs. Comparison of 2013 site photographs with earlier (1996) site photographs do indicate a possible slight increase in bed level, but the historical aerial photographic record of the site from 1937 and 1967, and examination of upstream multiple channel bedrock controlled sites, show that the planform is relatively stable albeit that the size of the active channel is reducing. Small amounts of cobble habitat found in 1990's, which are still present at the site in 2013, but there are indications that sedimentation is problematic (Sukdeo *et al*., 2014; Begg, 1978; Tharme, 1996 and Louw, 1996).
IHI Instream: PES: C, Confidence 2.9 IHI Riparian: PES: C, Confidence 3.3
The instream IHI is mainly impacted by deteriorated water quality resulting in increased nutrients and benthic growth which leads to bed modification. Decreased baseflows and increased sediment loads within the system has also contributed to bed modification. The biggest impacts on the riparian IHI area is a high occurrence of alien vegetation, along with wood harvesting and clearance which has resulted in bank structure and connectivity modification. Increased nutrients within the system has favoured alien species with a preference for these conditions
Riparian vegetation: PES: C/D, Confidence: 3.1
The marginal zone is fairly narrow (0.5 – 1 m) and dominated by grasses (mainly *Paspalum distichum*), sedges (mainly *Juncus effasusand Cyperus eragrostis*) and reeds. In localised areas there are clumps of Madumbe (*Colocasia*

esculenta) and the aquatic plant *Ceratophyllum*. Marginal zone cover for instream fauna is generally high, with inundated roots, stems, grass and overhanging vegetation. Grazing pressure in the zone has likely favoured grasses at the expense of sedges. The lower zone is similar to marginal zone, with Madumbe, *C. dives, Syzygium cordatum, Ficus sur* and the alien perennial *Sesbanea punicea*. Reduced flooding disturbance may have favoured alien species, the main impact in the zone. The upper zone comprises mainly grass and sedge, shrubs and smaller trees. Dominant species are *Acacia sieberiana, A. nilotica, Rauvolfia, S. cordatum, Senna, Sesbanea, Cromalina, Lipia* and *F. sur.* Vegetation removal (wood cutting and clearing due to san mining) is high in the zone. The macro-channel bank is dominated by woody vegetation (with savanna influence of the Eastern Valley Bushveld). Dominant species are *Trichilia emetica, Spirostachys africana, A. sieberiana* and *Melia azedarach*. High flow channels are dominated by grasses and sedges (*Juncus* spp.), with *Combretum erythrophyllum* scattered. Terraces are dominated by woody species, with similar species to the upper zone and bank, with extensive clearing and wood harvesting. Alien species abundance is high.
Fish: PES: B/C, Confidence: 3
Based on the available fish distribution data and expected habitat composition, sixteen indigenous fish species had a high to definite probability of occurrence under reference conditions. These included three freshwater eel species (*Anguilla bicolor*, *A. marmorata*and*A. mossambica*), five cyprinids (*Barbus gurneyi, L. natalensis, B. paludinosus, B. trimaculatus* and*B. viviparus*), oneclariid (*C. gariepinus*), three gobies (*Awaous aeneofuscus*, *Glossogobius giuris* and *Glossogobius callidus*), threecichlids (*O. mossambicus, Pseudocrenilabrus philander*and *Tilapia sparrmanii*) while the predominantly estuarine species *Acanthopagrus berda* may also frequent the reach. 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 slightly tomoderately reduced FROC. There is no evidence that the FROC of the eels, gobies and clariid species have been impacted notably under present conditions. The FROC of the eels species were slightly reduced due to reduced base flows resulting in decreased fast habitats (for juveniles). The FROC of *B. gurneyi* is estimated to be reduced due to water quality and habitat deterioration (sedimentation), together with the impact by predatory alien fish species (*L. macrochirus* and *M. salmoides*). Decrease in base flow also resulted in loss of fast habitat availability and condition (sedimentation) for *L. natalensis*, resulting in a decrease in the FROC of this species. The presence and abundance of alien predatory is also estimated to be the primary cause for a reduced FROC of the cichlids.
Macro-invertebrates: PES: B/C, Confidence: 3
A total of 32 SASS5 taxa were recorded during the field survey in June 2012 compared to 73 expected under natural conditions. Under these conditions, the SASS score was 207 with an ASPT of 6.4, which reflects a “Good” condition and is “Largely natural with few modifications”. The suitability of the river for taxa with a preference for very high flows was moderate (50% of expected taxa), and for high flows was also moderate (65% of expected taxa). Sensitive taxa included Philopotamidae and Perlidae, and taxa expected but not recorded included Prosopistomatidae and Oligoneuridae. The suitability of the river for taxa with a preference for SIC instream habitats was good (67% of expected taxa), but riverine vegetation was low (38% of expected taxa). The lower vegetation integrity can be ascribed to an encroachment of alien vegetation. Taxa expected but not recorded included Platycnemidae and Lestidae. The suitability of the river for taxa with a high requirement for unmodified physico-chemical conditions was moderate (67% of expected taxa) while there was an occurrence of 44% of the expected taxa with a preference for moderate water quality. Adverse conditions that might influence the water quality could be the increased nutrients. Taxa expected but not recorded included Prosopistomatidae and Oligoneuridae.

The PES EcoStatus is a C ECand the EcoStatus models are provided electronically.The major issues that have caused the change from reference condition were decreased base flows that have impacted to some extent on habitat availability and abundance for aquatic biota. Major non-flow related impacts included deteriorated water quality, catchment erosion and the presence of alien invasive vegetation. There is a high occurrence of alien vegetation species and two predatory alien fish species in the reach. Alien invasive vegetation in the riparian zones along with wood harvesting and clearance has led to a general loss of connectivity and bank modification in 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. The EIS is moderate, however the instream component of the EIS is high, and therefore an attempt should be made to improve the PES, which can be achieved by non-flow related measures (catchment management, alien vegetation removal etc.) and flows do not need to increase. The REC will therefore indicate the improvement, but an EWR for improved flows will not be set.

5.4 ALTERNATIVE ECOLOGICAL CATEGORY

The scenario included key driver change associated with a new upstream dam which would result in:

- Decreased base flows and floods.
- Increased sedimentation of riffles and fine accumulation in pools.
- Vegetation species composition change with a higher occurrence of grasses and shrubs, and a decrease in sedges.
- Increased nutrients.

Each component was adjusted to indicate the metrics that will react to the scenarios. The changes in the rule based models for the AEC are provided electronically and summarised inTable 5.2.

Table 5.2 Mv_I_EWR2: Alternative Ecological Category

Physico-chemical variables: AEC: D
An upstream dam (within approximately 5 - 10 km) will result in reduced baseflows and floods, and impacts on temperature and oxygen regimes. An impact on salt, toxic and nutrient levels would also be anticipated due to reduced dilution flows at low flows. A C/D category is anticipated, but a D category would be reached if impacts on baseflows are substantial.
Geomorphology: AEC: D
The scenario would result in a large decline of sediment supply, as well as a large reduction in flood frequencies and durations. Scouring of the channel bed (channel coarsening and armouring of the bed) and narrowing of the main channel together with abandonment of many braided/secondary channels and backwaters would occur, resulting in reduced instream habitat area and diversity. Bars and banks would be flooded less often, encouraging vegetation encroachment and stabilisation.
Riparian vegetation: AEC: D
The historical trend at the site shows a general increase in woody cover over time. One of the roles of flooding disturbance would be to interrupt this trend (which would resume) by scouring out woody vegetation and opening up microsites available for recolonisation. Reducing flooding disturbance will promote the rate of increase towards dense woody cover and will likely change species composition as competition results is a loss of species diversity (especially non-woody species). Some of the increase in woody cover will be by terrestrial species, hence terrestrialisation of the riparian zone is expected, which may extend as low as the lower sub-zone. Reduced base flows are likely to result in increases in non-woody vegetation in the marginal zone, and if sediment is available the zone may encroach towards the active channel (assumes an unaltered change to the frequency or duration of zero flow).
Fish: AEC: C
Decreased substrate quality (increased sedimentation, nutrients due to algae) coupled with decreased availability of fast habitats can be expected to further reduce the FROC of eels (juveniles) and *L. natalensis*. Further deterioration in water quality (especially increased nutrients) is expected to reduce the FROC of species with a high requirement for unmodified water quality, such as *B. gurneyi* and to a lesser degree *B. viviparus*. The FROC of minnows such as *B. viviparus* and *B. trimaculatus* may also be slightly reduced due to loss of habitats under reduced baseflow conditions.
Macro-invertebrates: AEC: C/D
Seven taxa are expected to disappear. Thus a total of 25 SASS5 taxa are expected compared to 73 expected under natural conditions. Under these conditions, the SASS score will be 131 with an ASPT of 5.2, which reflects a “Poor” condition and is “Largely modified”. The occurrence of taxa with a preference for very fast flowing water is expected to be reduced from 5 to 1 species out of 10 expected species (50% to 13%), while the taxa with a preference for fast flowing water are expected to be reduced from 5 to 4 species out of 9 expected species (56% to 67%). The overall % change in flow dependence of the species assemblage is 41% and can be attributed to flows can be attributed to the expected decreased flows and floods due to the proposed new dam. The occurrence of taxa with a preference for loose cobbles is expected to be reduced from 12 to 5 species out of 18 expected species (67% to 28%). The overall % change in indicators of specific habitat is 32% and can be attributed to sedimentation in different habitats. The occurrence of taxa with a preference for unmodified physico-chemical conditions is expected to be reduced from 4 to 1 species out of 6 expected species (67% to 17%), while the taxa with a preference for moderate physico-chemical conditions are expected to be reduced from 16 to 11 species out of 16 expected species (69% to 44%). The overall % change to indicators of modified water quality is 44% and can be attributed to the increased nutrients. Taxa with a preference to high flows of good water quality in cobble riffles that are expected to disappear from the system are Hydropsychidae, Perlidae, Philopotamidae, Heptageniidae and Trichorythidae, while Chlorocyphidae will disappear due to changes in vegetation, and Athericidae due to sedimentation.

5.5 ECOCLASSIFICATION SUMMARY

The EcoClassification results are summarised in Table 5.3.

Table 5.3 Mv_I_EWR2: Summary of EcoClassification results

Component	PES	REC	AEC↓
IHI Hydrology	B/C		
Physico chemical	C	C	D
Geomorphology	C	C	D
Fish	B/C	B	C
Invertebrates	B/C	B	C/D
Instream	B/C	B	C/D
Riparian vegetation	C/D	C/D	D
EcoStatus	C	B	C/D
Instream IHI	C		
Riparian IHI	C		
EIS	MODERATE		

6 EWR REQUIREMENTS: MVOTI RIVER (MV_I_EWR2)

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.

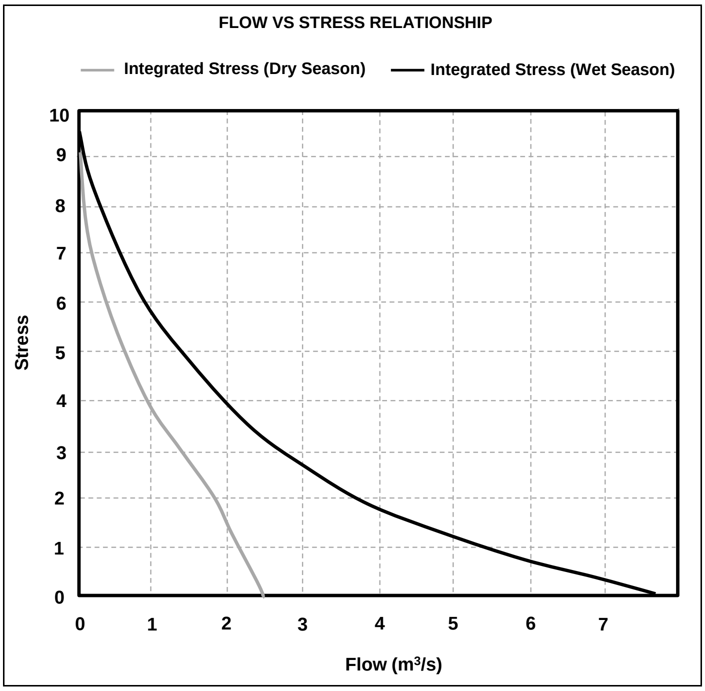

Figure 6.1 Mv_I_EWR2: Stress index

Table 6.1 Mv_I_EWR2: 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	2.24	Adequate fast habitats to ensure limited stress for Perlidae: ▪ 21% FS. ▪ 17% FI. ▪ 18% FD. ▪ 22% FCS. ▪ 16% VFCS.	5.49	Habitat very similar to natural conditions with limited stress expected. Critical habitat for indicator species (*L. natalensis*) are as follows: ▪ 4 % FS. ▪ 16% FI. ▪ 49% FD.
5	0.82	Fast habitats largely reduced - adequate to maintain biota with moderate stress: ▪ 12%FS. ▪ 13%FI. ▪ 5%FD. ▪ 17%FCS. ▪ 4%VFCS.	1.53	Approximately 50% decrease in critical habitats of indicator species. Habitat composition include approximately: ▪ 16%FS. ▪ 16%FI. ▪ 11%FD.
8	0.36	High stress on indicator taxon due to very limited suitable fast habitats: ▪ 9%FS. ▪ 3%FI. ▪ 0.3%FD. ▪ 7% FCS. ▪ 1%VFCS.	0.36	Only 5% suitable habitats and FI will be lost if exceeded. Very limited breeding habitat and longitudinal connectivity. ▪ 3%FS. ▪ 1%FI. ▪ 0%FD.

6.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as March and September. Droughts are set at 90% exceedance (flow) and 10% exceedance (stress). Maintenance flows are set at 40% exceedance (flow) and at 60% exceedance (stress).

6.3 INSTREAM BIOTA REQUIREMENTS

The required stress to maintain the instream PES of a B/C was determined by specialists and descriptions of key stress points (Table 6.2) are provided below. The requirements are illustrated as flow duration curves in Figure 6.2.

Table 6.2 Mv_I_EWR2: Stress requirements and habitat and instream biota description

Instream PES: B	Dry season		Wet season	
Percentile	Flow (m^3/s)	Description	Flow (m^3/s)	Description
90% (drought)	0.26	Biota will be moderately stressed (6.6) but flow should be adequate to allow survival and ensure maintenance in PES: ▪ 8.4% FS. ▪ 2.7% FI. ▪ 0% FD. ▪ 3% FCS. ▪ 0% VFCS.	1.01	Biota will only be moderately stressed (6) and adequate fast habitats (abundance and diversity) will be maintained even under drought conditions: ▪ 12 % FS. ▪ 12.9 % FI. ▪ 4.9 % FD. ▪ 21% FCS. ▪ 7% VFCS.
60%	0.53	Moderate stress (5.1) but adequate fast habitats to maintain the biota in PES: ▪ 13.7% FS. ▪ 6.5% FI. ▪ 1.7% FD. ▪ 5% FCS. ▪ 0% VFCS.	2.03	Minimal stress (3.8) to biota to ensure adequate fast habitats to maintain biota (especially for large semi-rheophilic species *L. natalensis*) in healthy state: ▪ 18.6% FS. ▪ 17.4% FI. ▪ 16.1% FD. ▪ 22% FCS. ▪ 16% VFCS.

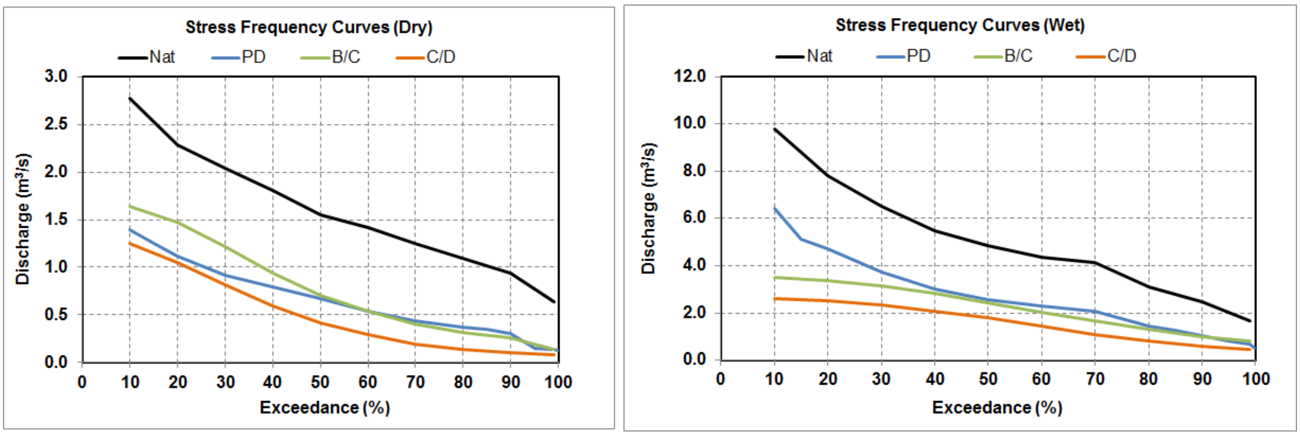

Figure 6.2 Mv_I_EWR2: Flow duration curves for the dry and wet season

6.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

The required low flows as determined by instream fauna are sufficient to inundate the lower limits of marginal zone vegetation (*C. dives* and *Juncus lomatophyllus* in particular) throughout the growing season and for 50-60% of the time in winter. The dominant hydrophilic grass (*Paspalumdistichum*) which covers large portions of the marginal and lower zones will be inundated (at its lower limit) for 50% of the time from Dec to Jun (up to 80% of the time in Mar) and for 20-30% of the time in winter. It is important to note that there are no zero flows. Confidence is high that the requested low flow regime (together with high flow requirements) will maintained the current ecological category of riparian vegetation.

6.5 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in Table 6.3and final high flow results are provided in Table 6.4.

Table 6.3 Mv_I_EWR2: Identification of instream functions addressed by the identified floods for riparian vegetation

Flood Class Flood Range (Peak in m^3/s)	Geomorphology and Riparian vegetation motivation	Fish flood functions						Macro-invertebrate 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 (10 - 20)	**Geomorphology:** This small flood is expected to scour the secondary channels to maintain backwaters, scour riffles. **Riparian vegetation:** These events are required to flood the marginal and lower zones, with patchy scouring and deposition that will maintain habitat and species diversity. They will also reduce the presence of terrestrial species (terrestrialisation) as well as facilitate temporary removal of some alien species. The duration of inundation of 5 events over the growing season will also help maintain non-woody vegetation, which is also important for its contribution to instream habitat for fish and macro-invertebrates.	√	√	√	√	√	√	√	√	√	√
CLASS II (40)	**Geomorphology:**This flood is expected to inundate the low terraces and activate the flood channels. **Riparian vegetation:** Together with the smaller floods this event will form the sixth flood during the growing season. It performs similar functions to the smaller floods but is particularly needed to facilitate recruiting opportunities for riparian woody species in the upper zone while also reducing the prevalence of woody vegetation lower in the riparian zone. It also activates high flow channels in the upper zone which support sedges and hydrophilic grasses.	√	√	√	√	√	√	√	√	√	√
CLASS III (50 - 60)	**Riparian vegetation:** This event is similar to the annual event but inundates to the current tree line of adult larger trees rather than just the sapling and juvenile bank. It is important to maintain the distinction between woody vegetation with high density (at higher elevation in the riparian zone) and low density (at lower elevations in the riparian zone).	√	√	√	√	√	√	√	√	√	√
CLASS IV (130 - 150)	**Geomorphology:** This flood will inundate the high terraces, check veg encroachment and maintain the flood conveyance. **Riparian vegetation:** An infrequent large event needed to maintain (recruitment, reproduction, vigour) riparian woody species growing on the macro-channel bed as well as retard terrestrialisation of the same area.	√	√	√	√	√	√	√	√	√	√

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

Table 6.4 Mv_I_EWR2: The recommended number of high flow events required

Flood Class (Peak in m^3/s)	Flood requirements*	Months	Daily Ave.	Duration (days)
CLASS I(10 - 20)	5	Nov, Dec, Feb, Mar, Apr	12	4
CLASS II(40)	1	Jan	30	8
CLASS III(50 - 60)	1:2/3*	Summer	40	10
CLASS IV(130 - 150)	1:5*	Summer	100	12

*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 6.5) and an EWR rule (Table 6.6; Table 6.7). 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 6.8.

Table 6.5 Mv_I_EWR2: EWR table for Instream PES: B/C

Month	Low Flows		High Flows (m^3/s)	
	Drought (90%) (m^3/s)	60% (m^3/s)	Daily average (m^3/s)	Duration (days)
Oct	0.31	0.64		
Nov	0.39	0.84	12	4
Dec	0.49	1.03	12 40	4 10
Jan	0.64	1.34	30	8
Feb	0.83	1.65	12 100	4 12
Mar	1.01	2.03	12	4
Apr	0.90	1.89	12	4
May	0.87	1.56		
Jun	0.59	1.02		
Jul	0.36	0.69		
Aug	0.29	0.58		
Sep	0.27	0.55		

Table 6.6 Mv_I_EWR2: Assurance rules (m^3/s)for Instream PES: B/C

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.01	1.62	1.42	1.13	0.88	0.64	0.47	0.38	0.31	0.14
Nov	2.58	2.08	1.67	1.34	1.08	0.84	0.63	0.50	0.39	0.28
Dec	3.11	2.66	2.21	1.63	1.32	1.03	0.79	0.66	0.49	0.37
Jan	3.36	3.16	2.68	2.08	1.70	1.34	1.00	0.75	0.64	0.48
Feb	3.95	3.41	3.04	2.67	2.15	1.65	1.28	1.01	0.83	0.70
Mar	3.51	3.39	3.16	2.82	2.44	2.03	1.65	1.30	1.01	0.83
Apr	3.44	3.21	2.93	2.55	2.18	1.89	1.54	1.25	0.90	0.63
May	3.05	2.90	2.60	2.10	1.82	1.56	1.30	1.09	0.87	0.44
Jun	2.56	2.34	1.96	1.67	1.36	1.02	0.83	0.70	0.59	0.31
Jul	2.12	1.98	1.36	0.94	0.76	0.69	0.54	0.43	0.36	0.15

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Aug	1.89	1.48	1.01	0.86	0.72	0.58	0.45	0.36	0.29	0.13
Sep	1.70	1.52	1.26	0.97	0.73	0.55	0.42	0.33	0.27	0.14

Table 6.7 Mv_I_EWR2: Assurance rules (m^3/s)for Instream AEC: C/D

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.53	1.16	0.96	0.73	0.53	0.35	0.23	0.17	0.14	0.10
Nov	1.94	1.50	1.14	0.87	0.67	0.49	0.33	0.25	0.18	0.14
Dec	2.33	1.93	1.53	1.09	0.85	0.63	0.43	0.35	0.24	0.17
Jan	2.50	2.32	1.91	1.44	1.14	0.86	0.58	0.41	0.33	0.23
Feb	2.96	2.51	2.22	1.94	1.53	1.11	0.79	0.59	0.46	0.37
Mar	2.60	2.51	2.34	2.09	1.78	1.43	1.09	0.81	0.59	0.45
Apr	2.58	2.36	2.13	1.84	1.55	1.31	1.00	0.75	0.48	0.44
May	2.28	2.11	1.85	1.46	1.24	1.03	0.81	0.65	0.49	0.38
Jun	1.92	1.69	1.35	1.12	0.88	0.62	0.46	0.37	0.30	0.27
Jul	1.59	1.42	1.08	0.72	0.53	0.39	0.27	0.21	0.16	0.15
Aug	1.43	1.16	0.76	0.63	0.45	0.32	0.22	0.17	0.15	0.10
Sep	1.29	1.08	0.84	0.61	0.43	0.30	0.20	0.15	0.11	0.09

Table 6.8 Mv_I_EWR2: Summary of results as a percentage of the nMAR

EcoStatus	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
PES instream: B/C	273.96	168.84	48.3	17.6	19.4	7.1	67.7	24.7
AEC instream: C/D			33.4	12.2	17.6	6.4	51	18.6

7 ECOCLASSIFICATION: uMNGENI RIVER (MG_I_EWR2)

7.1 EIS RESULTS

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

- Diversity of types and features: Riffles, pools, overhanging vegetation and seep.
- Migration route: Important for the migration of eel species in the system.
- Rare and Endangered riparian species found in the area: *Cyathea capensis* var*. capensis* (Declining); *C. macowanii* (Declining); *G. perpensa* (Declining); *H.polymorpha* (Vulnerable); *Ilex mitis* var*. mitis* (Declining).
- Refugia and critical riparian habitat: Refugia for above rare and endangered riparian species.

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_I_EWR2: Present Ecological State

IHI Hydrology: PES: C/D, Confidence: 3
The nMAR is 228.19 MCM and the pMAR is 105.4 MCM (46.19% of the nMAR). There is a 54% difference in MAR between observed and modeled present hydrology due to impoundment at Midmar Dam and catchment development (afforestation, farm dams and irrigation water use). Water is abstracted from Midmar Dam to supply uMsunduze (Pietermaritzburg) and surrounding areas. There is an inter-basin transfer (referred to as MMTS) that transfers water from the Mooi River System (Mearns Weir) to the Midmar Dam catchment. The second phase of the MMTS is in the process of being constructed i.e. Springrove Dam in the Mooi River catchment, which will transfer additional volumes of water into the Midmar Dam catchment. The present day hydrology only reflects the impact of the first phase of the MMTS. Due to land use, baseflow volumes have changed from natural while floods have decreased and the frequency of moderate floods have changed. There is a constant net compensation release of 0.9 m^3/s from Midmar Dam. The release is in support of irrigation water use downstream of the dam and also to ensure sufficient flow at Howick Falls.
Physico-chemical variables: PES: C/D, Confidence:4
The 2012 Green Drop report for WWTW in the study area that potentially impact on rivers, showed the following wastewater risk ratings: Howick WWTW on the uMngeni River, eThekwini MM: **Low Risk** However, many water quality impacts have been reported in the uMngeni River downstream of Howick, e.g. a "sewage river" at an informal settlement between Howick West and Siphumelele, an inadequate Bridge Sewage Pump Station that often spills raw sewage straight into the uMngeni River, and other sewage spills into the Merrivale stream and into the uMngeni River below Howick Falls. These impacts result in high nutrient and toxic levels in the uMngeni downstream of Howick. The water quality status quo (DWA, 2013a) for the study identified SQ U20E-04243 where the EWR site is located, as a water quality hotspot. The deleterious impact of the Merrivale Stream on the uMngeni River is obvious, although conditions downstream are still poor in terms of nutrient and *E.coli* loads.
Geomorphology: PES: D, Confidence: 3.5
The site is located about 17 km downstream of the large Midmar Dam. A historical aerial photographic record of the site from 1937, 1944 and 1987 and comparisons with more recent imagery (2006, 2010, 2012 and 2013) confirm that the channel planform is fairly stable, but site investigations and other monitoring studies confirm that the site is impacted by flow and the effects of the dam. The greatest impacts are from the sediment trapping effects of the dam and highly altered flow (release) patterns downstream. Floods are extremely reduced. Excessive erosion results from the clear water, sediment hungry releases from dams. The site is currently characterized by cobbles and boulders, but this is because sand and gravels have been eroded away and are not replaced. As a consequence, the active channel has widened since the 1930's/1940's as much of the marginal zone (lower bank) has been eroded away by sediment-free dam releases. The river bed is now far more coarser (characterized by far larger sediments) than would have occurred naturally Hunter (2009). The local ecologist confirmed that bottom releases from Midmar result in extensive silt drapes over the river habitats.
IHI Instream: PES: D, Confidence 3.1 IHI Riparian: PES: C, Confidence 4
The instream IHI is mainly impacted by decreased base flow which increases sedimentation and floods due to Midmar Dam. Water quality problematic with increased nutrient loading within the system which has led to increased algal

growth ultimately leading to bed modification. Turbidity is high. The biggest impacts on the integrity of the instream riparian area are bank structure modification due to the presence of alien invasive species, vegetation removal and altered flow regime.
Riparian vegetation: PES: C, Confidence: 2.9
The marginal zone consists mainly of cobble/boulder and fast flowing water and is up to 3m in places. It is dominated by non-woody vegetation such as *C. dives, Cotula nigellifolia, Nasturtium officionale* (Watercress), *Setaria sphacelata, J. effasus* and some *P. australis*. The lower zone is broad, up to 15m in places and mostly dominated by non-woody vegetation, with stunted woody vegetation in parts (such as *S. cordatum, S. guineense,* and *F.sur*). Other areas are dominated by tall woody closed canopy mainly *S. guineense* and *S. cordatum*. Both the marginal and lower zones have been extended by regulated flows and vegetation zonation is distinct due to lack of flooding disturbance. At the site extensive sedge cover (mainly *C. dives*) has attracted seasonally high grazing and trampling by buffalo (*pers. Comm*., Hans Grobler) and warthog. The upper zone is narrow and mostly dominated by grasses (both terrestrial and riparian). Some areas are dominated by tall woody vegetation, mainly *S. cordatum, S. guineense, F. sur,* and *T. emetica*. The left bank is altered by and comprising mostly of road. The right bank is short and steep, mostly terrestrial woody vegetation, but including *Erythrina caffra*.
Fish: PES: E, Confidence: 2.5
Based on the available fish distribution data and expected habitat composition it is estimated that twelve indigenous fish species may have occurred in the reach under reference conditions. These included two freshwater eel species (*A. marmorata, A. mossambica*), the amphiliid *A. natalensis*, four cyprinids (*B. anoplus*, *B. gurneyi, L. natalensis and B. viviparus*), oneclariid (*C. gariepinus*), and fourcichlids (*O. mossambicus, Pseudocrenilabrus philander, Tilapia rendalli*and *Tilapia sparrmanii*). It is estimated that at least four species (*A. marmorata*, *A. mossambica*, *B. anoplus* and *B. gurneyi*) may have disappeared from this reach under present conditions. The loss of the eels is primarily attributed to migratory obstacles (various large dams such as Albert Falls and Inanda Dam)preventing these catadromous species to complete their life cycle. The loss of the two barbs is thought to be related to water quality deterioration (sludge releases from Midmar Dam as well as sewage spills) as well as the impact of alien predatory species (*L. macrochirus, M. punctulatus*, *M. dolomieu*, *Salmo trutta*). Severe decrease in the FROC of *A. natalensis* and *L. natalensis* is estimated due to the flow modification by Midmar Dam (decreased base flows resulting in loss of fast habitats), occasional flushing of bottom sediment/sludge from Midmar Dam (clogging gills, suffocation due to anoxic conditions) (these species is thought to utilize tributaries as refuge during unsuitable periods and will recolonise the Umgeni reach when conditions are suitable). Water quality deterioration, the impact of predatory alien species together with migration barriers are also thought to be responsible for reduced FROC of the barbs and cichlids.
Macro-invertebrates: PES: C, Confidence: 3
A total of 28 SASS5 taxa were recorded during the field survey in June 2012 compared to 45 expected under natural conditions. Under these conditions, the SASS score was 175 with an ASPT of 6.2, which reflects a “Good” condition and is “Largely natural with few modifications”. The suitability of the river for taxa with a preference for very high flows was moderate (57% of expected taxa), and for high flows was high (78% of expected taxa). Sensitive taxa included Hydropsychidaeand Perlidae, and taxa expected but not recorded included Prosopistomatidae and Oligoneuridae. The suitability of the river for taxa with a preference for SICinstream habitats was good (64% of expected taxa), but riverine vegetation was low (33% of expected taxa) which can be ascribed to an encroachment of alien vegetation and regulated flows. Taxa expected but not recorded included Oligoneuridae and Prosopistomatidae. The suitability of the river for taxa with a high requirement for unmodified physico-chemical conditions was moderate (57% of expected taxa) while there was an occurrence of 64% of the expected taxa with a preference for moderate water quality. Adverse conditions that might influence the water quality could be the increased nutrients. Taxa expected but not recorded included Prosopistomatidae and Oligoneuridae.

The PES EcoStatus is a C/D EC and the EcoStatus models are provided electronically. The major issues that have caused the change from reference condition were mainly flow related with decreased base flows and floods due to Midmar Dam resulting in a loss of flow diversity.Alien invasive vegetation, grazing pressure and species composition change in the riparian zones have led to a general loss of connectivity and bank modification in the reach. The decrease in baseflows has impacted to some extent on habitat availability and abundance for aquatic biota while deteriorated water quality possibly related to sedimentation and turbidity impact on the fish abundance.

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. The EIS is moderate; however the fish component has to improve to a D EC. The REC will therefore indicate the improvement, but an EWR for improved flows will not be set.

An AEC will also not be investigated due to the already highly changed flow regime. As alternative flow regime is governed by changed operating rules, AECs can be investigated if such an operational scenario is provided during further study phases.

7.4 ECOCLASSIFICATION SUMMARY

Due to the highly manipulated flows in the reach an AEC was not further investigated.The EcoClassification results are summarised in Table 7.2.

Table 7.2 Mg_I_EWR2: Summary of EcoClassification results

Component	PES and REC
IHI Hydrology	C/D
Physico chemical	C/D
Geomorphology	D
Fish	E* (D)
Invertebrates	C
Instream	D
Riparian vegetation	C
EcoStatus	C
Instream IHI	D
Riparian IHI	C
EIS	**MODERATE**

* Fish to improve to a D EC.

8 EWR REQUIREMENTS: uMNGENI RIVER (MG_I_EWR2)

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.

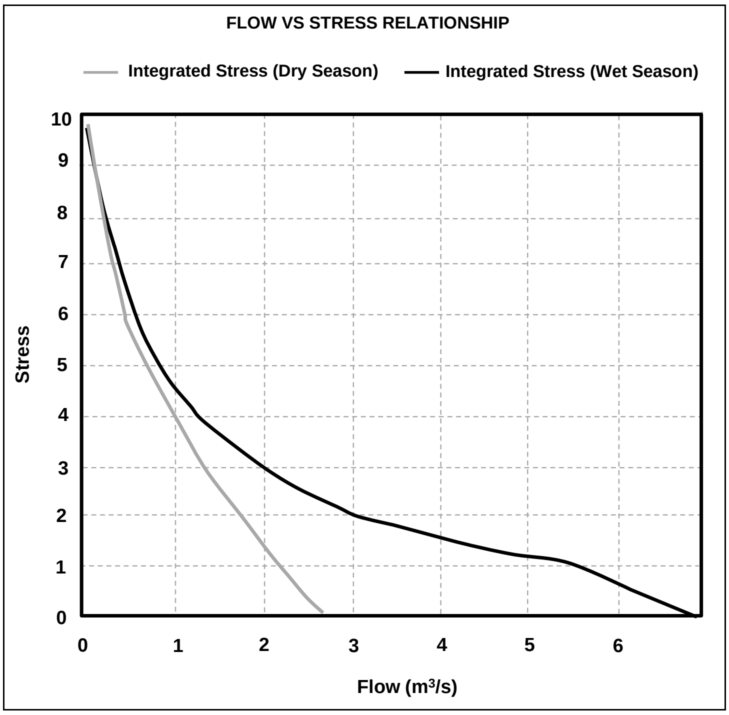

Figure 8.1 Mg_I_EWR2: Stress index

Table 8.1 Mg_I_EWR2: 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	2.20	Adequate fast habitats to ensure limited stress for *A. natalensis*: ▪ 14% FS. ▪ 15% FI. ▪ 22% FD. ▪ 27% (FCS. ▪ 17% VFCS.	5.94	Habitat very similar to under natural conditions with limited stress expected. Critical habitat for indicator species (*L. natalensis*) are as follows: ▪ 14% FS. ▪ 4% FI. ▪ 37% FD.
5	0.74	Although fast habitats are largely reduced it is adequate to maintain biota with moderate stress: ▪ 10%FS. ▪ 6%FI. ▪ 6%FD. ▪ 17%FCS. ▪ 5%VFCS.	0.84	Approximately 50% decrease in critical habitats of indicator species. Habitat composition include approximately: ▪ 10%FS. ▪ 8%FI. ▪ 7%FD.
8	0.20	Limited habitat resulting in high stress on instream biota: ▪ 3%FS. ▪ 2%FI. ▪ 8%FCS. ▪ No FD (0%) and VFCS (0%).	0.18	Only 5% suitable habitats and FD will be lost if exceeded. Very limited breeding habitat and longitudinal connectivity: ▪ 3%FS. ▪ 2%FI. ▪ 0%FD.

8.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as February and September. Droughts are set at 90% exceedance (flow) and 10% exceedance (stress). Maintenance flows are set at 40% exceedance (flow) and at 60% exceedance (stress).

8.3 STRESS WEIGHTINGS

8.4 INSTREAM BIOTA REQUIREMENTS

The required stress to maintain the instream PES of a D was determined by specialists and descriptions of key stress points (Table 8.2) are provided below. The requirements are illustrated as flow duration curves in Figure 8.2.

Table 8.2 Mg_I_EWR2: Stress requirements and habitat and instream biota description

PES: C	Dry season		Wet season	
Percentile	Flow (m^3/s)	Description	Flow (m^3/s)	Description
90% (drought)	0.45	Biota will be moderately stressed (6) but flow should be adequate to allow survival and ensure maintenance in PES: ▪ 7% FS. ▪ 5% FI. ▪ 4% FD. ▪ 3% FCS. ▪ 0% VFCS.	0.46	Moderate stress (6.5) but adequate fast habitats (abundance and diversity) will be maintained even under drought conditions: ▪ 8 % FS. ▪ 5 % FI. ▪ 4 % FD. ▪ 3% FCS. ▪ 0% VFCS.
60%	0.78	Moderate stress (5) but adequate fast habitats to maintain the biota in PES: ▪ 11% FS. ▪ 9% FI. ▪ 8% FD. ▪ 5% FCS. ▪ 0% VFCS.	1.00	Moderate stress (4.7) but adequate fast habitats to maintain biota (especially for large semi-rheophilic species *L. natalensis*) in healthy state: ▪ 11% FS. ▪ 11% FI. ▪ 12% FD. ▪ 6% FCS. ▪ 0% VFCS.

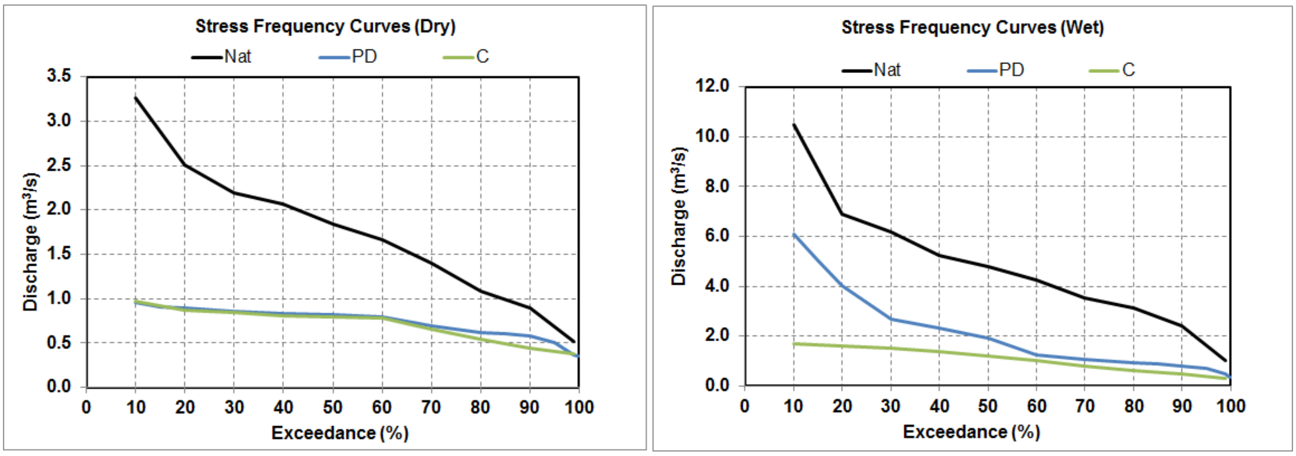

Figure 8.2 Mg_I_EWR2: Flow duration curves for thedry and wet season

8.5 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

Requested low flows will result in some inundation of reeds throughout the year although the presence of reeds at the site was limited. Partial inundation of marginal and lower zone vegetation (*Setaria sphacelata, Persicaria, Nasturtium* and *Cotula*) occurs for 60 - 70% of the time throughout summer, and throughout the year for 30 - 40% of the time. Larger sedges (*C. dives*) are only partially inundated in Mar (50% of the time) highlighting the importance of the high flows that were requested. The site remains perennial with no zero flows. Confidence is high that the suggested flow regime will maintain the ecological category of the riparian vegetation.

8.6 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in Table 8.3and final high flow results are provided in Table 8.4.

Table 8.3 Mg_I_EWR2: Identification of instream functions addressed by the identified floods for riparian vegetation

Flood Class Flood Range (Peak in m^3/s)	Geomorphology and Riparian vegetation motivation	Fish flood functions						Macro-invertebrate 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 (5 – 10)	**Geomorphology:**There are no geomorphological flood requirements for this site. The reach is located between the Midmar and Albert Falls Dam and almost all sand and gravel has been winnowed out of the site, creating an armoured cobble/boulder bed river. No flood flows for this site were therefore requested, since the reach is already sediment starved and large floods would merely accelerate sediment loss and a move away from natural habitat types. **Riparian vegetation:** These events are required to inundate non-woody vegetation growing in the valley bed and will help maintain the current zonation patterns.	√	√	√	√	√	√	√	√	√	√
CLASS II (20 - 30)	**Riparian vegetation**: The annual flood serves much the same role as the smaller floods but also inundates non-woody vegetation at higher elevation on the valley bed such as *J. effasus* and *A. napalensis*. Inundation due to this and smaller events will also keep the valley bed clear of woody vegetation.	√	√	√	√	√	√	√	√	√	√
CLASS III (50)	**Riparian vegetation:** This event activates and begins to inundate the tree line, including riparian trees such as *C. erythrophyllum* providing recruiting opportunities for woody species at higher elevations and maintaining some habitat patchiness in the lower areas.	√	√	√	√	√	√	√	√	√	√

No reliable gauges were present in the reach.

Table 8.4 Mg_I_EWR2: The recommended number of high flow events required

Flood Class (Peak in m^3/s)	Flood requirements*	Months	Daily Ave.	Duration (days)
CLASS I (5 – 10)	4	Dec - Apr	6	5
CLASS II (20 - 30)	1	Jan - Mar	20	6
CLASS III (50)	1:2*	Summer	50	10

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

8.7 EWR RESULTS

The results are provided as an EWR table (Table 8.5) and an EWR rule (Table 8.6). Detailed results are provided in the model generated report for each category in Appendix C. Note that the RDRM was linked to a C EC which is representative of the instream state or in this case, the invertebrate state (C EC). The instream could not be used as the EC is influenced by the very low fish PES (E EC).

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 8.7.

Table 8.5 Mg_I_EWR2: EWR table for PES and REC: C/D (RDRM - C)

Month	Low Flows		High Flows	
	Drought (90%) (m^3/s)	60% (m^3/s)	Daily average (m^3/s)	Duration (days)
Oct	0.52	0.82		
Nov	0.61	0.88		
Dec	0.66	1.03	6	5
Jan	0.56	1.06	20	6
Feb	0.45	0.99	6 50	5 10
Mar	0.96	1.64	6	5
Apr	0.84	1.39	6	5
May	0.58	1.02		
Jun	0.54	0.88		
Jul	0.51	0.85		
Aug	0.41	0.83		
Sep	0.46	0.81		

Table 8.6 Mg_I_EWR2: Assurance rules (m^3/s) for PES and REC: C/D (RDRM - C)

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.29	0.97	0.89	0.87	0.84	0.82	0.71	0.63	0.52	0.33
Nov	1.38	1.30	1.03	0.95	0.91	0.88	0.81	0.69	0.61	0.59
Dec	1.69	1.59	1.49	1.35	1.19	1.03	0.85	0.72	0.66	0.47
Jan	1.73	1.64	1.55	1.40	1.25	1.06	0.85	0.70	0.56	0.51
Feb	1.66	1.60	1.51	1.36	1.19	0.99	0.77	0.60	0.45	0.28
Mar	2.05	2.04	2.04	2.01	1.86	1.64	1.39	1.21	0.96	0.65
Apr	1.72	1.68	1.68	1.68	1.48	1.39	1.26	1.07	0.84	0.39
May	1.65	1.59	1.53	1.31	1.16	1.02	0.85	0.69	0.58	0.46
Jun	1.26	1.13	1.03	1.00	0.92	0.88	0.83	0.71	0.54	0.35

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Jul	1.06	0.98	0.94	0.91	0.88	0.85	0.75	0.65	0.51	0.38
Aug	1.07	0.95	0.90	0.87	0.86	0.83	0.67	0.59	0.41	0.40
Sep	1.01	0.90	0.87	0.84	0.83	0.81	0.68	0.56	0.46	0.39

Table 8.7 Mg_I_EWR2: Summary of results as a percentage of the nMAR

EcoStatus	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
PES/REC: C/D (C RDRM)	228.19	105.4	33.5	14.7	12.1	5.3	45.6	20

9 ECOCLASSIFICATION: uMNGENI RIVER (MG_I_EWR5)

9.1 EIS RESULTS

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

- Diversity of types and features: Riffles, pools and some overhanging vegetation.
- Species/taxon richness: Macro-invertebrates.
- Rare and endangered riparian/wetland species: Otters and water mongoose.

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_I_EWR5: Present Ecological State

IHI Hydrology: PES: C/D, Confidence: 3
The nMAR is 583.7 MCM and the pMAR is 245.3 MCM (42.03% of the nMAR). There is a 58% difference in MAR due to impoundment at Midmar, Albert Falls and Nagle dams and catchment development (afforestation, farm dams and irrigation water use). There is an inter-basin transfer (referred to as MMTS) that transfers water from the Mooi River System (Mearns Weir) to the Midmar Dam catchment. The second phase of the MMTS is in the process of being constructed i.e. Springrove Dam in the Mooi River catchment, which will transfer additional volumes of water into the Midmar Dam catchment. The present day hydrology only reflects the impact of the first phase of the MMTS. Water is abstracted from Midmar Dam to supply uMnsunduze (Pietermaritzburg) and surrounding areas. Water is also abstracted at Nagle Dam for the eThekwini supply area. Nagle Dam is supported from the upstream Albert Falls Dam. The uMnsunduze River confluences with the uMngeni upstream of EWR5. Henley Dam situated in the headwaters of the uMnsunduze River was decommissioned and acts as an evaporation pond. Discharges from the Darvill WWTW (Pietermaritzburg area) enter the uMnsunduze River and affect the flow and especially the water quality of the river as well as that of the Mgeni River downstream of the confluence of the two rivers. Umgeni water is currently investigating the potential of re-using effluent from the Darvill WWTW, which could have a future impact on the uMnsunduze River. Due to land use there is a decrease in base flow volumes as well as floods. The frequency of moderate floods has also decreased.
Physico-chemical variables: PES: C/D, Confidence:3.5
The EWR site is located between Nagle and Inanda dams. Water released from the lower layers of Nagle Dam results in higher nitrate, phosphate and turbidity levels than in the dam itself. The confluence of the uMngeni and uMnsunduze rivers is below Nagle Dam and upstream from the EWR site. Forestry and large-scale sugar cane production with related erosion potential is found in the central area of the uMngeni catchment, with limited, reasonably well-controlled pollution from cattle feedlots and poultry operations. There is some intensive vegetable production with resultant nutrient and pesticide problems. The water quality Status Quo report(DWA, 2013b) for the study identified SQ U20L-04435,where the EWR site is located downstream Nagle Dam, as a water quality hotspot.
Geomorphology: PES: C/D, Confidence: 3.5
The site is located in the lower Mgeni, just upstream of Inanda Dam. The large Midmar, Albert Falls and Nagle Dams in the middle reaches of the river dictate the present day flow patterns. Although the large upstream dams trap sediments, the high sediment production of the middle and lower catchment (DWA, 2013d) offsets these impacts. The historical aerial photographic record of the site from 1937 and 1967, together with more recent imagery from 2004, 2005, 2010 and 2013 show that the braided channel pattern (typical of river zones transporting high sediment loads) has been highly reduced, and a single channel pattern (less habitat diversity) is becoming increasingly common. The site is characterised by a cobble bed with outcrops of large boulders and occasional bedrock with sand moving over this, creating sedimentary bars multiple braid channels in the reach. Sand mining, even within the sensitive active channel, is widespread around the site, and the water is turbid and the riparian zone highly disturbed as a result. The site is impacted by altered flows and sediment loads from the catchment, as well as a high degree of riparian disturbance at the site.
IHI Instream: PES: D, Confidence 3 IHI Riparian: PES: D, Confidence 3.7
Instream integrity is impacted by altered baseflows and floods. Constant releases from dams have resulted in less instream habitat and channel width is decreasing due to reduced floods. Deteriorated water quality has resulted in bed modification due to high nutrient levels and increased algal growth. Bed and bank modification as well as longitudinal connectivity is impacted.

The riparian integrity is mainly impacted by the altered flow regime, presence of alien invasive vegetation and sandmining in the riparian zone. The sandmining has resulted in the alteration of the species composition which has exacerbated erosion and substrate exposure.
Riparian vegetation: PES: D, Confidence: 3.1
The marginal zone is scoured and dominated by Watercress (*Nasturtium officionale*). Instream cobbles highly covered by filamentous green algae. Dominated by non-woody vegetation, other than the alien species, mainly sedges (*Juncus* and *C. dives*) and some grasses (*Paspalum* and *Leptochloa*). Some isolated pockets of reeds also occur. The lower zone is broad, up to 10 m wide with a secondary channel. The sub-zone is dominated by *Juncus, Persicaria, C. dives, Setaria* and *Leptochloa*. Some areas are woody, mainly *S. cordatum, S. guineense* and *F. sur*. The presence of alien species is the main impact in the marginal and lower zones. The upper zone is wide and mostly alluvial. It is extensively disturbed by sand mining (which appears to have begun in 2010) with artificial pools that now support species found in the marginal and lower zones. Some areas are dominated by woody vegetation (*A. sieberiana, Dichrostachys cinerea, A. karoo*) but mostly non-woody vegetation young trees and weeds are a result of the disturbance. Under natural conditions the sub-zone would have a high density and cover of both riparian and terrestrial woody species. The Macro Channel Bank has been cleared in many places for sand mining or to create level camping sites. Otherwise the zone is dominated by woody vegetation, mainly *A. sieberiana, A. karoo, C. erythrophyllum* and terrestrial species. As with the upper zone, banks would naturally be more woody.
Fish: PES: D, Confidence: 3
Based on the available fish distribution data and expected habitat composition, fifteen indigenous fish species had a high to definite probability of occurrence under reference conditions. These included three freshwater eel species (*A. bengalensis labiata*, *A. marmorata, A. mossambica*), the amphiliid species *A. natalensis*, three cyprinids (*B. gurneyi, L. natalensis*and*B. viviparus*), oneclariid (*C. gariepinus*), three gobies (*Awaous aeneofuscus*, *Glossogobius giuris* and *Glossogobius callidus*) and four cichlids (*O. mossambicus, P. philander, T. rendalli and T. sparrmanii*). 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 to highly reduced FROC. Various records in region indicate that the eels may still occur notwithstanding the fact that some migration barriers (Inanda Dam) impact on their migration (catadromous). Although suitable habitat was available and sampled, *A. natalensis* was not present at the site and its FROC is thought to be reduced by decreased baseflow (flow modification) and sedimentation (loss of substrate quality). The FROC of *B. gurneyi* and *L. natalensis* is estimated to also be reduced due to water quality and habitat deterioration (sedimentation), together with the impact by predatory alien fish species (*M. salmoides*). Although the gobies were not sample during the EWR survey they are estimated to be present in the reach (more abundant in lower section but frequent the site at times). The presence and abundance of alien predatory is also estimated to be the primary cause for a reduced FROC of the cichlids.
Macroinvertebrates: PES: C/D, Confidence: 3
A total of 30 SASS5 taxa were recorded during the field survey in Jun 2012 compared to 58 expected under natural conditions. Under these conditions, the SASS score was 179 with an ASPT of 5.9, which reflects a “Fair” condition and is “Moderately modified”. The suitability of the river for taxa with a preference for very high flows was moderate (50% of expected taxa), and for high flows was high (89% of expected taxa). Sensitive taxa included Hydropsychidae and Perlidae, and taxa expected but not recorded included Philopotamidae and Oligoneuridae. The suitability of the river for taxa with a preference for SIC instream habitats was moderate (56% of expected taxa), but riverine vegetation was low (25% of expected taxa) which can be ascribed to fluctuations in flow. Taxa expected but not recorded included Platycnemidae and Lestidae. The suitability of the river for taxa with a high requirement for unmodified physico-chemical conditions was moderate (67% of expected taxa) while there was an occurrence of 38% of the expected taxa with a preference for moderate water quality. Adverse conditions that might influence the water quality could be the increased nutrients and higher salinity. Sensitive taxa included Heptageniidae and taxa expected but not recorded included Philopotamidae and Oligoneuridae.

The PES EcoStatus is a D EC and the EcoStatus models are provided electronically. The major issues that have caused the change from reference condition were decreased baseflows and floodsdue to upstream dams and general landuse in the upper catchment.Flow modification has impacted on habitat availability and abundance for aquatic biota. Non-flow related impacts include deteriorated water quality (uMnsunduze inflows etc. and increased sedimentation). Alien invasive vegetation species, vegetation removal and sandmining have led to a general loss of connectivity and bank modification.The presence of two predatory alien fish species in the reach contribute to the D EC.

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

9.4 ECOCLASSIFICATION SUMMARY

Due to the highly manipulated flows in the reach an AEC was not further investigated.The EcoClassification results are summarised in Table 9.2.

Table 9.2 Mg_I_EWR5: Summary of EcoClassification results

Component	PES and REC
IHI Hydrology	C/D
Physico chemical	C/D
Geomorphology	C/D
Fish	D
Invertebrates	C/D
Instream	C/D
Riparian vegetation	D
EcoStatus	D
Instream IHI	D
Riparian IHI	D
EIS	**MODERATE**

10 EWR REQUIREMENTS: uMNGENI RIVER (MG_I_EWR5)

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.

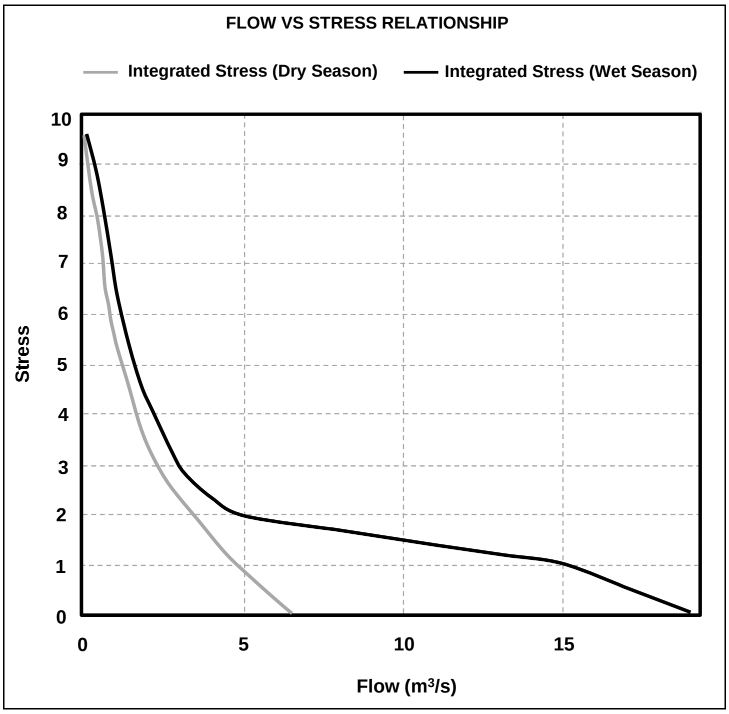

Figure 10.1 Mg_I_EWR5: Stress index

Table 10.1 Mg_I_EWR5: 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	4.48	Adequate fast habitats to ensure limited stress for *A. natalensis*: ▪ 7% FS. ▪ 12% FI. ▪ 41% FD. ▪ 24% FCS. ▪ 28% VFCS.	16.52	Habitat very similar to under natural conditions with limited stress expected. Critical habitat for indicator species (*L. natalensis*) are as follows: ▪ 3% FS. ▪ 6% FI. ▪ 70% FD.
5	1.08	Although fast habitats are largely reduced it is adequate to maintain biota with moderate stress: ▪ 7%FS. ▪ 3%FI. ▪ 18%FD. ▪ 22%FCS. ▪ 7%VFCS.	1.58	Approximately 50% decrease in critical habitats of indicator species. Habitat composition include approximately: ▪ 5%FS. ▪ 7%FI. ▪ 21%FD.
8	0.39	Limited habitat resulting in high stress on instream biota : ▪ 2%FS. ▪ 13%FI. ▪ 14%FCS. ▪ 3%VFCS.	0.63	Very limited breeding habitat and longitudinal connectivity ▪ 5% FS. ▪ 8% FI. ▪ 7% FD.

Stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
		▪ N no FD (0%).		

10.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as February and September. Droughts are set at 90% exceedance (flow) and 10% exceedance (stress). Maintenance flows are set at 40% exceedance (flow) and at 60% exceedance (stress).

10.3 INSTREAM BIOTA REQUIREMENTS

The required stress to maintain the instream PES of a C/D was determined by specialists and descriptions of key stress points (Table 10.2) are provided below. The requirements are illustrated as flow duration curves in Figure 10.2.

Table 10.2 Mg_I_EWR5: Stress requirements and habitat and instream biota description

Instream PES: C/D	Dry season		Wet season	
Percentile	Flow (m^3/s)	Description	Flow (m^3/s)	Description
90% (drought)	1.39	Biota will only be moderately stressed (4.5) and flow should be more than adequate to allow survival and ensure maintenance in PES: ▪ 5% FS. ▪ 7% FI. ▪ 21% FD. ▪ 24% FCS. ▪ 8% VFCS.	2.29	Biota will only be moderately stressed (4) and adequate fast habitats (abundance and diversity) will be maintained even under drought conditions: ▪ 10% FS. ▪ 7% FI. ▪ 28% FD. ▪ 28% FCS. ▪ 13% VFCS.
60%	2.30	Relatively low stress (2.8) with more than adequate fast habitats to maintain the biota in PES: ▪ 10% FS. ▪ 7% FI. ▪ 28% FD. ▪ 28% FCS. ▪ 13% VFCS.	2.61	Relatively low stress (3.3) and adequate fast habitats to maintain biota (especially for large semi-rheophilic species *L. natalensis*) in healthy state: ▪ 9% FS. ▪ 7% FI. ▪ 32% FD. ▪ 28% FCS. ▪ 15% VFCS.

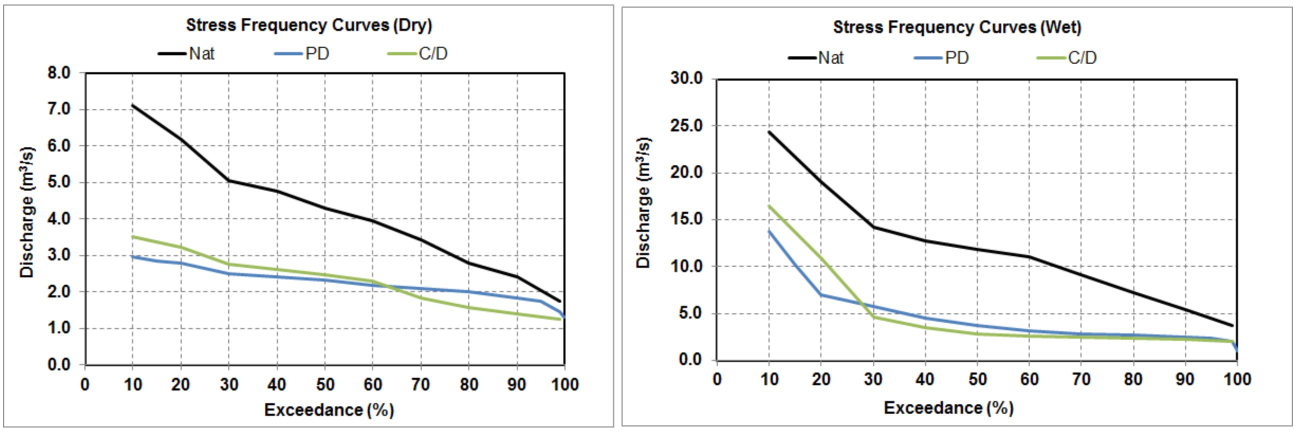

Figure 10.2 Mg_I_EWR5: Flow duration curves for thedry and wet season

10.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

Marginal zone vegetation (limited at the site) will be largely inundated throughout the year (*C. dives* and *Nasturtium officionale*), while lower zone sedges and grasses (*J. effasus* and *S. sphacelata* respectively) are partially inundated for 40% of the time throughout summer (70% in March and April) and only 10% of the time throughout the year. Woody vegetation along the lower zone (*S. guineense*) is activated for 10% of the time in summer, sufficient to maintain soil moisture but also highlighting the importance of high flows. The site remains perennial with no occurrence of zero flows. Confidence is high that low flows (together with high flows) will maintain the ecological category of riparian vegetation

10.5 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in Table 10.3 and final high flow results are provided in Table 10.4.

Table 10.3 Mg_I_EWR5: Identification of instream functions addressed by the identified floods for riparian vegetation

Flood Class Flood Range (Peak in m^3/s)	Geomorphology and Riparian vegetation motivation	Fish flood functions						Macro-invertebrate 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 (10 - 15)	**Riparian vegetation:** Required to inundate marginal zone vegetation to the upper limit of species dominant in the zone and more restricted to it i.e. not including species with wider ranges (tolerance) of flow requirements. Prevents establishment of terrestrial or alien species (some species, and at least temporarily) 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 active channel. Promotes accumulation of nutrient/sediment. Causes small disturbance but promotes habitat and species diversity. Indicators used were *C. dives*, *N. officionale* and *J. effasus.*	√	√	√	√	√	√	√	√	√	√
CLASS II (20 - 30)	**Riparian vegetation:** Does the same function as the marginal zone flood but includes the lower zone. It is likely to also be important for some scouring in the marginal zone, which contributes to habitat and species diversity. This will benefit quicker responding species to persist (or dominate for a time) such as the mix between non-woody and woody vegetation. Inundates the lower zone. Indicators used were *Ludwigia octovalvis*.	√	√	√	√	√	√	√	√	√	√
CLASS III (40 - 50)	**Geomorphology:**These small events are important for flushing sands, activating gravels and for inundating the low paired terraces. **Riparian vegetation:** Used recruiting saplings of the upper zone woody species as indicator.This is an important event for keeping the marginal and lower zone free of non-obligate woody species.	√	√	√	√	√	√	√	√	√	√
CLASS IV (80 – 100)	**Geomorphology:** This was the effective discharge flood class for sands and gravels, accounting for approximately 25% of the long term sediment movement potential. **Riparian vegetation:** Inundates large proportion of upper zone and adult trees. Prevents terrestrialisation of the riparian zone.	√	√	√	√	√	√	√	√	√	√
CLASS V (> 200)	**Geomorphology:** This is the effective discharge flood class for small cobbles, and is necessary to maintaining the predominantly cobble bed substrate, inundate the high terrace at the site but most importantly, to reactivate secondary channels in the reach in order to mitigate against the abandonment of the braided sections which are associated with high habitat diversity. **Riparian vegetation:** Inundates large trees causing removal of some and maintaining overall biodiversity.	√	√	√	√	√	√	√	√	√	√

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

Table 10.4 Mg_I_EWR5: The recommended number of high flow events required

Flood Class (Peak in m^3/s)	Flood requirements*	Months	Daily Ave.	Duration (days)
CLASS I (10 - 15)	4	Nov - Apr	10	6
CLASS II (20 - 30)	2	Dec - Mar	20	8
CLASS III (40 - 50)	1	Jan - Mar	40	12
CLASS IV (80 – 100)	1:3*	Summer	80	
CLASS V (> 200)	1:5	Summer	150	

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

10.6 EWR RESULTS

The results are provided as an EWR table (Table 10.5) and an EWR rule (Table 10.6). Detailed results are provided in the model generated report for each category in Appendix C. The flows are linked to the instream PES and REC of a C/D as the EcoStatus and riparian vegetation is in a D largely due to the presence of alien vegetation (non-flow related).

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 10.7.

Table 10.5 Mg_I_EWR5: EWR table for Instream PES and REC: C/D

Month	Low Flows		High Flows (m^3/s)	
	Drought (90%) (m^3/s)	60% (m^3/s)	Daily average (m^3/s)	Duration (days)
Oct	1.12	1.83		
Nov	1.33	2.53	10 80	6
Dec	1.45	2.83	20 150	8
Jan	1.59	3.02	10	6
Feb	1.86	2.76	20	6
Mar	2.49	3.94	10 40	6 12
Apr	2.13	3.18	10	6
May	1.77	3.01		
Jun	1.48	2.79		
Jul	1.27	2.52		
Aug	1.08	2.25		
Sep	1.01	2.22		

Table 10.6 Mg_I_EWR5: Assurance rules (m^3/s) for Instream PES and REC: C/D

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	4.49	3.36	3.18	2.89	2.77	1.83	1.80	1.44	1.12	0.97
Nov	6.99	3.84	3.67	3.39	3.25	2.53	2.00	1.63	1.33	1.14
Dec	11.48	9.13	4.88	3.72	3.47	2.83	2.23	1.79	1.45	1.29
Jan	12.96	11.16	8.17	5.05	3.91	3.02	2.39	1.92	1.59	1.57
Feb	15.40	12.79	8.34	4.60	3.53	2.76	2.34	2.03	1.86	1.70
Mar	13.60	12.76	11.05	7.70	5.80	3.94	3.58	2.97	2.49	2.03

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Apr	12.43	11.34	7.20	5.10	3.84	3.18	3.18	2.77	2.13	1.70
May	5.52	4.80	4.29	3.73	3.45	3.01	2.43	2.02	1.77	1.33
Jun	4.04	3.79	3.45	3.10	3.01	2.79	2.21	1.80	1.48	1.14
Jul	3.84	3.29	2.96	2.70	2.60	2.52	1.91	1.55	1.27	1.04
Aug	3.59	3.17	2.81	2.57	2.44	2.25	1.55	1.41	1.08	1.00
Sep	3.65	3.34	2.86	2.70	2.57	2.22	1.73	1.32	1.01	0.86

Table 10.7 Mg_I_EWR5: Summary of results as a percentage of the nMAR

EcoStatus	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
PES/REC Instream: C/D	583.7	245.3	133.57	22.9	17.03	2.9	150.6	25.8

11 ECOCLASSIFICATION: MKOMAZI RIVER (MK_I_EWR1)

11.1 EIS RESULTS

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

- Unique instream biota: *L. natalensis*, *A. natalensis (*regional endemics).
- Intolerance to flow: Four macro-invertebrate taxa and two fish species.
- Diversity of habitat types and features: Riffles, pools, and island with vegetation.
- Rare and Endangered riparian species: *Gymnosporia bachmannii* (Vulnerable); *H. polymorpha* (Vulnerable); *I. mitis* var*. mitis* (Declining.
- Refugia and critical riparian habitat: Refugia for above rare and endangered riparian species

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 Mk_I_EWR1: Present Ecological State

IHI Hydrology: PES: A/B, Confidence: 3
The nMAR is 683.2 MCM and the pMAR is 660.7 MCM (96.7% of the nMAR). There is a 3.3% difference in MAR between observed and modeled present hydrology. The storage regulation in the catchment is low and the only dams in the area include a number of small farm dams in tributaries and a few instream dams. It is mainly a mountainous area, where nature reserves and the Sani Pass Tourism area are located. There is some agriculture and community water use. The main activities in the catchment include forestry, cultivation, irrigation, grazing and rural water use from low density rural settlements. Due to land use, baseflow volumes have changed slightly from natural while floods have decreased.
Physico-chemical variables: PES: A/B, Confidence:4
The 2012 Green Drop report for WWTW in the study area that potentially impact on rivers, showed the following wastewater risk ratings: ▪ Bulwer WWTW nearest the Luhane River, Sisonke DM: **High Risk**, with non-compliance with effluent quality discharge standards. Note that the WWTW is a distance away from the rivers being evaluated. There is little urban development in most of the Mkomazi catchment, with most of the residential and industrial development associated with the towns of Umkomaas on the coast and Ixopo and Richmond inland. Primary impacts in the area are elevated sediment loads due to activities such as overgrazing and high population numbers, resulting in elevated instream turbidity. However, no major water quality issues or hotspots were identified and the water quality of the Mkomazi is considered Good.
Geomorphology: PES: A/B, Confidence: 4
This EWR site was surveyed in 1997/8 as part of an earlier IFR study. Comparisons with those earlier site photographs, as well as the historical aerial photographic record from 1963, 1967, 2008 and 2014, attest to the stable condition of this bedrock-base reach. Despite the increased catchment erosion evident from aerial photography, the reach is high energy and resilient to sedimentation. There are no large dams in the catchment, and limited afforestation, grazing and only small farm dams have had little impact on the river condition (DWA, 2013d, unpublished site photographs from 1998 IFR study).
IHI Instream: PES: B, Confidence 3.3 IHI Riparian: PES: C, Confidence 3.8
Instream integrity is impacted by forestry and abstraction to a certain extent. There is some bed and bank modification due to instream weirs and water quality deterioration resulting in increasedsiltation and algal growth. Riparian integrity is impacted mainly by the presence of alien invasive vegetation and overgrazing. These impacts result in substrate exposure and increased erosion. The structural changes in vegetation impact on the longitudinal and lateral connectivity.
Riparian vegetation: PES: C, Confidence: 2.9
The marginal zone is mostly open bedrock and faster flowing water. It is dominated by a mix of woody and non-woody vegetation, mostly *S. sphacelata, Cyperus longus, Salix mucronata,* and *Gomphostigma virgatum.* The lower zone is

similar to the marginal zone, is also mostly open bedrock with similar species as well as *Miscanthus capensis*. Increased woody cover as a result of reduced flooding disturbance and the prevalence of alien species are the main impacts. The upper zone is broad and flat, mostly bedrock with a simple channel. Trampling and grazing pressure is high and the zone is dominated by mostly non-woody vegetation (*Juncus, Setaria, Miscanthus* and also *C. erythrophyllum*). The Macro Channel Bank is steep and high with a distinct tree line at the bottom indicated by *C. erythrophyllum. C. erythrophyllum* also occurs high up on the top of the bank. Invasion by alien species is high, mostly Bramble, Mauritian thorn and Wattle.
Fish: PES: B/C, Confidence: 3
Based on the available fish distribution data and expected habitat composition, four indigenous fish species had a high to definite probability of occurrence under reference conditions. These included one freshwater eel species (*A. mossambica*), the amphiliid species *A. natalensis* and two cyprinids (*B. anoplus*and*L. natalensis*). 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 slightly reduced FROC. All of the expected species except the eel were found to still be abundant at the site during sampling in 2013. The slight reduction in FROC of species are estimated to be associated with slight reduced flows (*A. natalensis* and *L. natalensis*), sedimentation and algal growth on rocky substrates (*A. natalensis* and *L. natalensis*), presence of some downstream migration barriers (*A. mossambica* and to some extent *L. natalensis*) and the presence of predatory alien *M. salmoides* (*B. anoplus* and *L. natalensis* juveniles).
Macro-invertebrates: PES: C/D, Confidence: 3
A total of 28 SASS5 taxa were recorded during the field survey in June 2012 compared to 47 expected under natural conditions. Under these conditions, the SASS score was 187 with an ASPT of 6.6, which reflects a “Fair” condition and is “Moderately modified”. The suitability of the river for taxa with a preference for very high flows was moderate (75% of expected taxa), and for high flows was good (78% of expected taxa) which can be attributed to the absence of zero flows and major infrastructure and thus floods are not affected. Sensitive taxa included Prosopistomatidae and Perlidae, and taxa expected but not recorded included Philopotamidae and Trichorythidae. The suitability of the river for taxa with a preference for SIC instream habitats was good (52% of expected taxa), but riverine vegetation was low (20% of expected taxa). The lower vegetation integrity can be ascribed to a lack of favourable marginal vegetation overhang. Taxa expected but not recorded included Chlorolestidae and Lestidae. The suitability of the river for taxa with a high requirement for unmodified physico-chemical conditions were good (100% of expected taxa) while there was an occurrence of 44% of the expected taxa with a preference for moderate water quality.Adverse conditions that might influence the water quality could be sedimentation and increased nutrients. Taxa expected but not recorded included Elmidae, Trichorythidae, and Athericidae.

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 and alien invasive vegetation in the riparian zones have led to substrate exposure and increased erosion. Increased sedimentation has resulted in higher turbidity. Migration barriers and alien fish species affect the reach.

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

11.4 ALTERNATIVE ECOLOGICAL CATEGORY

The scenario included key driver change associated with a new upstream dam which would result in:

- Decreased base flows and floods.
- Some change in water temperature.
- Erosion of the marginal zone due to scour.
- Decreased fines within the system.
- Increased alien vegetation due to decreased floods.

Each component was adjusted to indicate the metrics that will react to the scenarios. The changes in the rule based models for the AEC are provided electronically and summarised inTable 11.2.

Table 11.2 Mk_I_EWR1: Alternative Ecological Category

Physico-chemical variables: AEC: B/C
The upstream dam will result in decreased floods and base flows, and associated temperature and oxygen impacts. Nutrient levels may increase due to lower dilution flows.
Geomorphology: AEC: C
The bedrock nature of the site makes it fairly resilient to morphological change, but where cobbles and gravels are present, armouring of the bed could occur, and some settling of suspended fines may occur during the more prolonged low flow periods. When sediment-hungry flood releases occur, these would erode the lower banks and reduce sedimentary marginal zones.
Riparian vegetation: AEC: C/D
One of the roles of flooding disturbance would be to scour out woody vegetation and open up microsites available for recolonisation. Reducing flooding disturbance will promote the rate of increase of woody cover. Some of the increase in woody cover will be by terrestrial species, hence terrestrialisation of the riparian zone is expected, which may extend as low as the lower sub-zone. Since the riparian zone already has a high degree of invasion by alien perennial species (such as Wattle and Bramble), reduced flooding disturbance will facilitate their increase and expansion. Reduced base flows, together with increased scour are likely to result in reductions in non-woody vegetation in the marginal and lower zones.
Fish: AEC: C
The reduced FROC of species will be associated with decreased flows resulting in a loss of fast habitats (impacting on especially *A. natalensis* and *L. natalensis*), the presence of the new dam will result in a migration barrier within the reach (especially impacting on *L. natalensis*), while the marginal zone will erode and result in a loss of overhanging vegetation (especially impacting on *B. anoplus*).
Macro-invertebrates: AEC: C/D
Six taxa are expected to disappear. Thus a total of 22 SASS5 taxa are expected compared to 47 expected under natural conditions. Under these conditions, the SASS score will be119 with an ASPT of 5.4, which reflects a “Poor” condition and is “Largely modified”. The occurrence of taxa with a preference for very fast flowing water is expected to be reduced from 6 to 3 species out of 8 expected species (75% to 37%), while the taxa with a preference for fast flowing water are expected to be reduced from 6 to 5 species out of 9 expected species (78% to 67%). The overall % change in flow dependence of the species assemblage is 41% which can be attributed to the expected decreased flows and floods due to the proposed new dam. The occurrence of taxa with a preference for loose cobbles is expected to be reduced from 9 to 4 species out of 17 expected species (52% to 24%). The overall % change in indicators of specific habitat is 40% which can be attributed to the eroding of the marginal zone and a decrease in fines. The occurrence of taxa with a preference for unmodified physico-chemical conditions is expected to be reduced from 5 to 3 species out of 5 expected species (100% to 60%), while the taxa with a preference for moderate physico-chemical conditions are expected to be reduced from 7 to 4 species out of 16 expected species (44% to 25%). The overall % change to indicators of modified water quality is 42%. The lowering in status related to water quality can be attributed to the change in water temperature. Taxa with a preference to high flows of good water quality in cobble riffles that are expected to disappear from the system are Prosopistomatidae, Perlidae, Philopotamidae, Heptageniidae and Psephenidae.

11.5 ECOCLASSIFICATION SUMMARY

The EcoClassification results are summarised in Table 11.2.

Table 11.3 Mk_I_EWR1: Summary of EcoClassification results

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

12 EWR REQUIREMENTS: MKOMAZI RIVER (MK_I_EWR1)

12.1 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 12.1 and a description of the habitat associated with the stress is provided in Table 12.1.

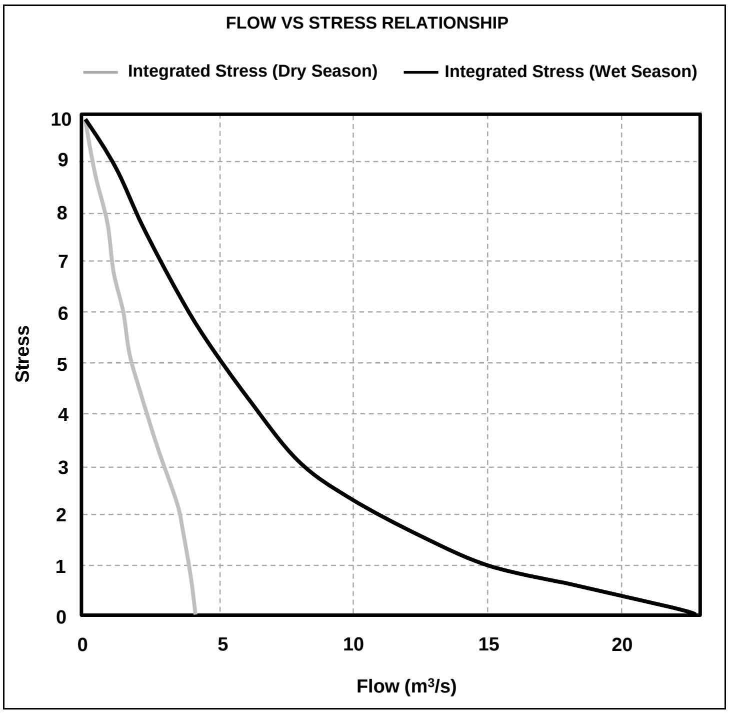

Figure 12.1 Mk_I_EWR1: Stress index

Table 12.1 Mk_I_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	3.84	Adequate fast habitats to ensure limited stress for *A natalensis*: ▪ 5% FS. ▪ 7% FI. ▪ 17% FD. ▪ 4% FCS. ▪ 1% VFCS.	14.9	Habitat very similar to under natural conditions with limited stress expected. Critical habitat for indicator species (*L. natalensis*) are as follows: ▪ 46% FS. ▪ 10% FI. ▪ 51% FD.
5	1.78	Fast habitats largely reduced - adequate to maintain biota with moderate stress: ▪ 4%FS. ▪ 2%FI. ▪ 6%FD. ▪ 2%FCS. ▪ No VFCS (0%).	5.16	Approximately 50% decrease in critical habitats of indicator species. Habitat composition include approximately: ▪ 8%FS. ▪ 7%FI. ▪ 24%FD.
8	0.75	Limited habitat resulting in high stress on instream biota. ▪ 1%FS. ▪ 1% FI. ▪ 2%FD. ▪ 1% FCS. ▪ No VFCS (0%).	2.17	Very limited breeding habitat and longitudinal connectivity ▪ 4%FS. ▪ 4%FI. ▪ 8%FD.

12.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as February and August. Droughts are set at 90% exceedance (flow) and 10% exceedance (stress). Maintenance flows are set at 30% exceedance (flow) and at 70% exceedance (stress).

12.3 INSTREAM BIOTA REQUIREMENTS

The required stress to maintain the instream PES of a B/C was determined by specialists and descriptions of key stress points (Table 12.2) are provided below. The requirements are illustrated as flow duration curves in Figure 12.2.

Table 12.2 Mk_I_EWR1: Stress requirements and habitat and instream biota description

Instream PES: B/C	Dry season		Wet season	
Percentile	Flow (m^3/s)	Description	Flow (m^3/s)	Description
90% (drought)	1.07	Biota will be notably stressed (7) but flow should be adequate to allow survival and ensure maintenance in PES: ▪ 2.9% FS. ▪ 1.9% FI. ▪ 4% FD. ▪ 1% FCS. ▪ 0% VFCS.	5.13	Biota will be moderately stressed (5) but adequate fast habitats (abundance and diversity) will be maintained even under drought conditions: ▪ 7 % FS. ▪ 8 % FI. ▪ 26 % FD. ▪ 5% FCS. ▪ 2% VFCS.
70%	1.56	Biota will be moderately stressed (5.8) but adequate fast habitats to maintain the biota in PES: ▪ 4% FS. ▪ 2.3% FI. ▪ 6.3% FD. ▪ 2% FCS. ▪ 0% VFCS.	7.41	Biota will have minimal stress (3.3) and adequate fast habitats to maintain biota (especially for large semi-rheophilic species *L. natalensis*) in healthy state: ▪ 8.6% FS. ▪ 10% FI. ▪ 35% FD. ▪ 6% FCS. ▪ 3% VFCS.

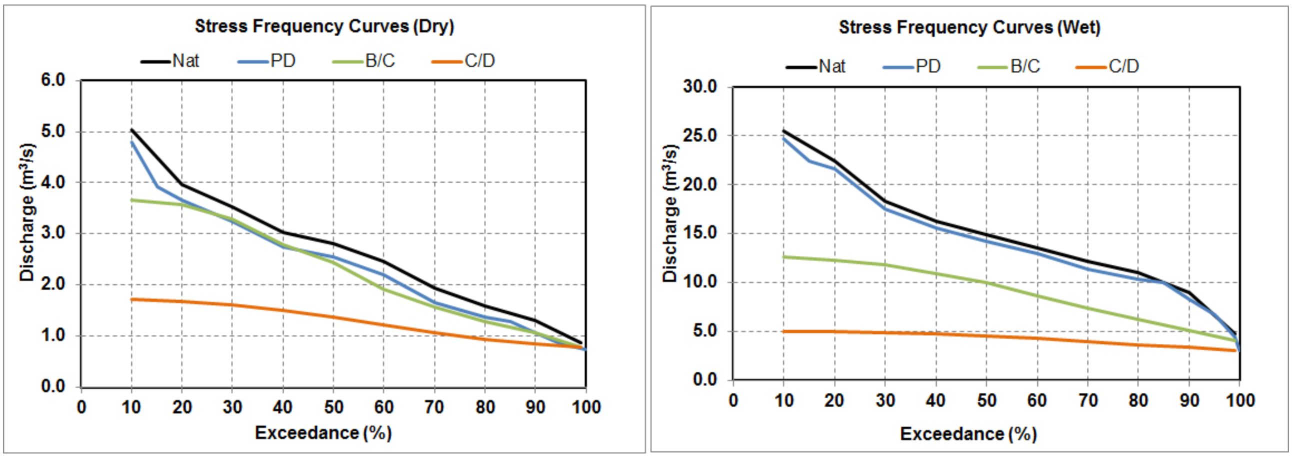

Figure 12.2 Mk_I_EWR1: Flow duration curves for thedry and wet season

12.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

Marginal zone vegetation was scattered and patchy at the site. Sedges that did occur along the channel (*C. longus*) will be partially inundated for 60-70% of the time throughout the year. Specified low flows will result in no inundation of grass tufts or woody vegetation in the valley bed (*S. sphacelata* and *S. mucronata* respectively), but flows are likely to be sufficient for survival and persistence. Specified high flows will be important for the maintenance of riparian vegetation. The site remains perennial with no zero flows. Overall the ecological category of riparian vegetation is unlikely to change with specified flows.

12.5 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in Table 12.3 and final high flow results are provided in Table 12.4.

Table 12.3 Mk_I_EWR1: Identification of instream functions addressed by the identified floods for riparian vegetation

Flood Class Flood Range (Peak in m^3/s)	Geomorphology and Riparian vegetation motivation	Fish flood functions						Macro-invertebrate 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 (30 – 50)	**Geomorphology:** These small events are important for flushing sands through the site.Secondary channels are activated and sediments are flushed from the channel bed. **Riparian vegetation:** These events are required to flood the marginal and lower zones, maintain habitat and species diversity and also reduce the presence of terrestrial species (terrestrialisation) in these zones. The duration of inundation of three events over the growing season will also help maintain non-woody vegetation and hydrophilic woody vegetation (such as *G. virgatum* and *S. mucronata*), which is also important for its contribution to instream habitat for fish and macro-invertebrates. Indicators in these zones include *C. longus*, *S. sphacelata*, *S. mucronata*, *A. napalensis*and *Gomphostigma virgatum*.	√	√	√	√	√	√	√	√	√	√
CLASS II (70 - 80)	**Riparian vegetation:** Together with the smaller floods these event will result in five floods during the growing season. These events perform similar functions to the smaller floods but are particularly needed to facilitate recruiting opportunities for riparian woody species in the upper zone while also reducing the prevalence of woody vegetation lower in the riparian zone. Additional indicators used include *Miscanthus junceus*.	√	√	√	√	√	√	√	√	√	√
CLASS III (100 - 120)	**Geomorphology:**This is the effective discharge flood class for sands, accounting for more than 25% of the long term transport potential. The channel would be scoured and bars will be inundated, and sedimentation will be kept in check. **Riparian vegetation:** This event inundates all features and vegetation on the macro-channel valley bed. Its primary function is to maintain heterogeneity in the riparian zone and prevent dominance by a single or few species (such as aliens). Additional indicators used include *C. erythrophyllum*.	√	√	√	√	√	√	√	√	√	√
CLASS IV (>300)	**Geomorphology:**This is the effective discharge flood class for cobbles, accounting for more than 80% of the long term transport potential. **Riparian vegetation:** An infrequent large event needed to maintain (recruitment, reproduction and vigour) riparian woody species on the macro-channel bank and retard terrestrialisation of the banks.	√	√	√	√	√	√	√	√	√	√

The availability of high flows was verified using the observed data at gauge U1H005 (downstream of the EWR site).

Table 12.4 Mk_I_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 (30 – 50)	3	Nov - Apr	30	5
CLASS II (70 - 80)	2	Feb, Mar	70	6
CLASS III (100 - 120)	1	Feb, Mar	90	7
CLASS IV (>300)	1:5*	Summer	250	

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

12.6 EWR RESULTS

The results are provided as an EWR table (Table 12.5) and EWR rule (Table 12.6 and Table 12.7). 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 12.8.

Table 12.5 Mk_I_EWR1: EWR table for Instream PES and REC: B/C

Month	Low Flows		High Flows	
	Drought (90%) (m^3/s)	70% (m^3/s)	Daily average (m^3/s)	Duration (days)
Oct	1.369	2.059		
Nov	2.015	3.057	30	5
Dec	2.727	4.512	250	
Jan	4.163	6.262	30	5
Feb	5.088	7.345	70 90	6 7
Mar	6.904	8.828	70	6
Apr	5.081	6.645	30	5
May	3.234	4.498		
Jun	1.819	2.711		
Jul	1.228	2.004		
Aug	1.066	1.562		
Sep	1.008	1.676		

Table 12.6 Mk_I_EWR1: Assurance rules (m^3/s) for Instream PES and REC: B/C

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	4.509	4.310	3.946	3.556	2.746	2.307	2.059	1.681	1.369	1.129
Nov	6.221	6.168	5.493	4.958	4.094	3.375	3.057	2.483	2.015	1.657
Dec	9.606	9.142	8.552	7.856	6.384	5.217	4.512	3.599	2.727	2.047
Jan	11.615	11.568	10.917	9.920	8.588	7.157	6.262	5.065	4.163	3.435
Feb	12.495	12.224	11.717	10.843	9.908	8.603	7.345	6.147	5.088	4.092
Mar	13.961	12.670	12.646	11.785	9.891	9.308	8.828	7.793	6.904	6.415
Apr	11.270	11.140	10.539	9.910	8.655	7.586	6.645	5.675	5.081	4.710
May	7.925	7.925	7.679	7.028	6.008	5.125	4.498	3.657	3.234	2.423
Jun	5.494	5.256	4.822	4.446	3.636	3.059	2.711	2.160	1.819	1.297
Jul	4.816	4.385	3.733	3.462	2.773	2.277	2.004	1.512	1.228	0.750
Aug	3.666	3.570	3.348	3.006	2.434	1.910	1.562	1.290	1.066	0.790
Sep	3.697	3.397	2.787	2.682	2.174	1.774	1.676	1.317	1.008	0.852

Table 12.7 Mk_I_EWR1: Assurance rules (m^3/s) for AEC: C/D

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.095	2.017	1.884	1.775	1.529	1.458	1.394	1.222	1.083	0.970
Nov	2.852	2.837	2.583	2.439	2.223	2.072	2.015	1.765	1.562	1.388
Dec	4.140	4.045	3.860	3.708	3.295	3.007	2.834	2.465	2.060	1.703
Jan	4.826	4.820	4.673	4.474	4.164	3.837	3.642	3.251	2.951	2.880
Feb	4.951	4.916	4.851	4.739	4.562	4.306	3.974	3.647	3.339	3.077
Mar	5.933	5.578	5.555	5.550	5.550	5.549	5.486	5.274	5.271	5.190
Apr	4.712	4.710	4.562	4.470	4.188	3.993	3.872	3.869	3.866	3.798
May	3.573	3.573	3.514	3.364	3.131	2.963	2.827	2.505	2.401	2.259
Jun	2.534	2.439	2.283	2.201	1.992	1.904	1.804	1.551	1.451	1.297
Jul	2.231	2.050	1.786	1.750	1.543	1.428	1.359	1.103	0.976	0.750
Aug	1.720	1.677	1.604	1.501	1.368	1.217	1.070	0.949	0.852	0.781
Sep	1.728	1.566	1.329	1.328	1.171	1.170	1.145	0.949	0.779	0.731

Table 12.8 Mk_I_EWR1: Summary of results as a percentage of the nMAR

EcoStatus	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
PES/REC instream: B/C	683.17	660.72	171.78	25.1	67.31	9.9	239.09	35
AEC: C/D			88.96	13	57.57	8.4	146.53	21.4

13 ECOCLASSIFICATION: MKOMAZI RIVER (MK_I_EWR2)

13.1 EIS RESULTS

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

- Unique instream biota: *L. natalensis*, *A. natalensis (*regional endemics).
- Intolerance to flow: Nine macro-invertebrate taxa and two fish species and *H. polymorpha* (Vulnerable).
- Diversity of habitat types and features: Rapids, riffles, pools, overhanging vegetation and reeds.
- Migration route: Important for the migration of eel species in the system.
- Rare and Endangered riparian species: *C. capensis* var*. capensis* (Declining); *I. mitis* var*. mitis* (Declining).
- Refugia and critical riparian habitat: Refugia for above rare and endangered riparian species.
- Migration corridor: Important for bird species.

13.2 PRESENT ECOLOGICAL STATE

The PES reflects the changes in terms of the EC from reference conditions. The summarised PES information is provided in Table 13.1 and water quality and diatom information is provided in Appendix A and B respectively.

Table 13.1 Mk_I_EWR2: Present Ecological State

IHI Hydrology: PES: A/B, Confidence: 3
The nMAR is 890.9 MCM and the pMAR is 838.4 MCM (94.1% of the nMAR). There is a 5.9% difference in MAR between observed and modeled present hydrology. The storage regulation in the catchment is low and the only dams in the area include a number of small farm dams in tributaries and a few instream dams. The upper part of the catchment is mainly a mountainous area, where nature reserves and the Sani Pass Tourism area are located. There is some agriculture and community water use. The main activities in the catchment include forestry, cultivation, irrigation, some sugarcane, cattle farming and community water use from low density rural settlements. The development of the upstream Mkomazi River Development Project (Smithfield Dam) will have a significant impact on the Mkomazi River and the effect of this future development will be observed at this EWR site.Due to land use, baseflow volumes have changed slightly from natural while floods have decreased.
Physico-chemical variables: PES: A/B, Confidence:3.5
Overgrazing and high population densities in the upper, middle and lower parts of the catchment have resulted in some increased sediment yields. However, no major water quality issues or hotspots were identified and the water quality of the Mkomazi is considered good.
Geomorphology: PES: B, Confidence: 4
This EWR site was surveyed in an earlier IFR study in 1997/8. Comparisons with those earlier site photographs, as well as the historical aerial photographic record from 1937, 1962, 1967, 2008 and 2010, attest to the stable condition of this cobble/boulder dominated river bed. Some secondary channels have been lost, possibly due to vegetation encroachment and increased channel stabilisation from this. There are no large dams upstream of the site, and relatively small changes in hydrology, but some increased catchment erosion can be expected to have increased sediment loads. Small (active) lateral bars have increased since 1998, most likely simply in response to a period of fewer very large floods (and tending back to a condition similar to that seen in the late 1960's). It is also possible that these increased bars may be in response to slightly higher sediment loads of the river, but this is likely a minor role, if any, in these observed changes (DWA, 2013d; unpublished site photographs from 1998 IFR study).
IHI Instream: PES: B, Confidence 3.5 IHI Riparian: PES: B/C, Confidence 3.7
Instream integrity is impacted by catchment erosion which results in bed modification due to increased sediment. Deteriorated water quality also contributes to bed modification due to algal growth on substrate. Riparian integrity is impacted mainly by the presence of alien invasive vegetation. This results in substrate exposure and increased erosion. The structural changes in vegetation impact on longitudinal connectivity.

Riparian vegetation: PES: B, Confidence: 2.9
The marginal zone is narrow, mostly cobble, and dominated by reeds (*P. australis*), sedges (*C. marginatus* and *C. longus*) and grasses (*Setaria* and *Arundinella*). Non-woody vegetation is the dominant vegetation type providing instream and inundated vegetation cover for fauna, but *S. mucronata* (Cape Willow) also occurs in the zone and provides overhanging cover for instream fauna in many places. The lower zone is also narrow and dominated by non-woody vegetation with a mix of cobble and some alluvial lateral bars. Vegetation is dominated by reeds (*P.australis*), sedges (*C.marginatus* and *C. longus*) and grasses (*A. napalensis* and *Miscanthus capensis*). Woody components consist of *S. mucronata* and *F. sur*. The upper zone is dominated by woody vegetation, mostly *S. guineense, C. erythrophyllum* and *F. sur*. Perennial alien species cover is high, mostly *Chromalaena, Caesalpinia, Sesbanea* and Wattle. The Macro Channel Bank is steep and dominated by woody vegetation: dense tall trees and shrubs including *mitis* and *Celtis africana*. There is a floodplain upstream of the site which is dominated by *A. karoo* and *A. gerardii.*The main impacts at the site consist of increased reed and sedge cover and invasion by perennial alien species.
Fish: PES: B, Confidence: 3
Based on the available fish distribution data and expected habitat composition, seven indigenous fish species had a high to definite probability of occurrence under reference conditions. These included two freshwater eel species (*A. marmorata*and*A. mossambica*), the amphiliid species *A. natalensis*, three cyprinids (*B. anoplus, L. natalensis*and*B. viviparus*) and oneclariid (*C. gariepinus*). 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. The presence of downstream migration barriers limits the migratory success of the eels (*A. marmorata* and *A. mossambica*) to some extent. Reduced flows result in a decrease in the availability of fast habitats, impacting on species with a preference for this biotope (such as juvenile eels, *A. natalensis* and *L. natalensis*). The presence and abundance of alien predatory*M. salmoides*is also estimated to be contributing to the decreased FROC of species such as *L. natalensis* (especially juveniles), and the smaller cyprinid species (*B. anoplus* and *B. viviparus*).
Macro-invertebrates: PES: B, Confidence: 3
A total of 26 SASS5 taxa were recorded during the field survey in June 2012 compared to 51 expected under natural conditions. Under these conditions, the SASS score was 173 with an ASPT of 6.6, which reflects a "Good" condition and is "Largely natural with few modifications". The suitability of the river for taxa with a preference for very high flows was moderate (54% of expected taxa), and for high flows was high (78% of expected taxa). Sensitive taxa included Hydropsychidae and Perlidae, and taxa expected but not recorded included Prosopistomatidae and Oligoneuridae. The suitability of the river for taxa with a preference for SIC instream habitats was low (40% of expected taxa), and riverine vegetation was very low (18% of expected taxa). The lower scores can be ascribed to sedimentation and lack of overhanging vegetation habitats. Sensitive taxa included Perlidae and Pyralidae; and taxa expected but not recorded included Chlorocyphidae. The suitability of the river for taxa with a high requirement for unmodified physico-chemical conditions was high (71% of expected taxa) while there was an occurrence of 33% of the expected taxa with a preference for moderate water quality. Adverse conditions that might influence the water quality could be traces of pollution and higher turbidity. Taxa expected but not recorded included Prosopistomatidae and Oligoneuridae.

The PES EcoStatus is a B 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. Catchment erosion has increased and alien invasive vegetation in the upper riparian zone has led to substrate exposure. Alien predatory fish species affect the reach.

13.3 RECOMMENDED ECOLOGICAL CATEGORY

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability there-of. The EIS was HIGH and although an improvement is normally required, most components are already in a B EC except for fish which is impacted by alien species. The REC was therefore set to maintain the PES.

13.4 ALTERNATIVE ECOLOGICAL CATEGORY

The scenario included key driver change associated with a new upstream dam which would result in:

- Decreased base flows and floods.
- Some change in water temperature and decreased turbidity.
- Encroachment of non-woody vegetation and more reeds in the marginal
- Reduced scour resulting in increased sedimentation.
- Less mobile beds.
- Increased alien vegetation due to decreased floods.

Each component was adjusted to indicate the metrics that will react to the scenarios. The changes in the rule based models for the AEC are provided electronically and summarised inTable 13.2.

Table 13.2 Mk_I_EWR2: Alternative Ecological Category

Physico-chemical variables: AEC: B
Impacts of the upstream dam will be reduced due to the increased distance from the dam. Small impacts on turbidity and temperature may be expected.
Geomorphology: AEC: C
The bed of this site is cobble/boulder dominated, so it would be fairly resilient to change, but the active channel could be expected to reduce with lower flows, and reduced floods would promote vegetation encroachment. Reduced scour and reduced cobble activation may slightly degrade the inchannel habitat.
Riparian vegetation: AEC: C
As with Mk_I_EWR1, reducing flooding disturbance will promote the rate of increase of woody cover along lateral bars and in the upper zone and bank. Some of the increase in woody cover will be by terrestrial species or alien perennial species. Reduced base flows, together with increased sediment deposition are likely to result in increases in non-woody vegetation in the marginal and lower zones, particularly as the marginal zone encroaches towards the active channel. Reedbeds are likely to intensify.
Fish: AEC: C
It is estimated that under this scenario the fish assemblage will be negatively impacted. The change and reduction in FROC of the species is estimated to be due to loss of habitat (reduced flows) that will impact on species with a preference for fast habitats (juvenile eels*A. marmorata* and *A. mossambica*, *A. natalensis* and *L. natalensis*). Slight increase in sedimentation of rocky substrates may also impact in the feeding and spawning success of these species. An encroachment of vegetation in the marginal zone is expected and hence may favor species with a preference for overhanging vegetation such as *B. anoplus* and *B. viviparus*.
Macro-invertebrates: AEC: C
None of the taxa are expected to disappear, but abundances will change; lower sensitive species numbers and higher tolerant species numbers. Thus a total of 26 SASS5 taxa are expected compared to 51 expected under natural conditions. Under these conditions, the SASS score will be 173 with an ASPT of 6.6, which reflects a “Good” condition and is “Largely natural with few modifications. The lower MIRAI scores related to flows can be attributed to the expected decreased flows and floods due to the proposed new dam. The lower MIRAI scores related to habitat can be attributed to the encroachment of none-woody plants and more reeds, as well as reduced scouring and increased sedimentation. The lower MIRAI scores related to water quality can be attributed to the change in water temperature.

13.5 ECOCLASSIFICATION SUMMARY

The EcoClassification results are summarised in Table 13.3.

Table 13.3 Mk_I_EWR2: Summary of EcoClassification results

Component	PES and REC	AEC↓
IHI Hydrology	A/B	
Physico chemical	A/B	B
Geomorphology	B	C
Fish	B	C
Invertebrates	B	C
Instream	B	C
Riparian vegetation	B	C
EcoStatus	B	C
Instream IHI	B	
Riparian IHI	B/C	
EIS	HIGH	

14 EWR REQUIREMENTS: MKOMAZI RIVER (MK_I_EWR2)

14.1 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 14.1 and a description of the habitat associated with the stress is provided in Table 14.1.

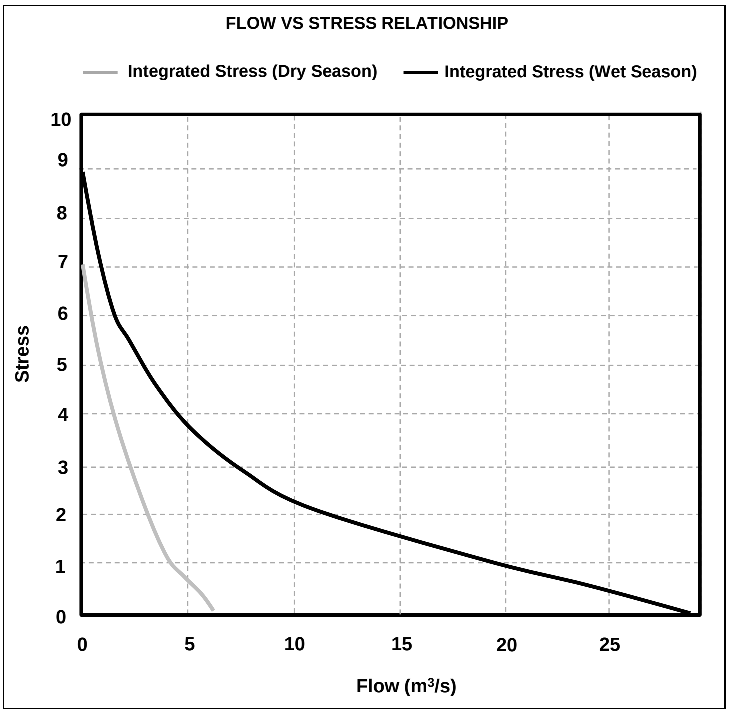

Figure 14.1 Mk_I_EWR2: Stress index

Table 14.1 Mk_I_EWR2: 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	6.27	Adequate fast habitats to ensure limited stress for *A. natalensis*: ▪ 10% FS. ▪ 8% FI. ▪ 33% FD. ▪ 27% (FCS. ▪ 20% VFCS.	19.44	Habitat very similar to under natural conditions with limited stress expected. Critical habitat for indicator species (*L. natalensis*) are as follows: ▪ 5% FS. ▪ 6% FI. ▪ 61% FD.
5	0.89	Although fast habitats are largely reduced it is adequate to maintain biota with moderate stress: ▪ 12%FS. ▪ 11%FI. ▪ 5%FD. ▪ 25%FCS. ▪ 7%VFCS.	3.12	Approximately 50% decrease in critical habitats of indicator species. Habitat composition include approximately: ▪ 9%FS. ▪ 11%FI. ▪ 22%FD.
8	0.04	Limited fast habitat resulting in high stress on instream biota: ▪ 10%FS. ▪ 0%FI. ▪ 0%FD. ▪ 23% FCS.	0.26	Only 13% suitable habitats and FD will be lost if exceeded. Very limited breeding habitat and longitudinal connectivity: ▪ 10%FS. ▪ 3%FI. ▪ 0%FD.

Stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
		▪ 4%VFCS.		

14.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as February and August. Droughts are set at 90% exceedance (flow) and 10% exceedance (stress). Maintenance flows are set at 30% exceedance (flow) and at 70% exceedance (stress).

14.3 INSTREAM BIOTA REQUIREMENTS

The required stress to maintain the instream PES of a B/C was determined by specialists and descriptions of key stress points (Table 14.2) are provided below. The requirements are illustrated as flow duration curves in Figure 14.2.

Table 14.2 Mk_I_EWR2: 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
90% (drought)	1.50	Biota will be slightly stressed (4) and flow will be suitable to ensure maintenance in PES: ▪ 11% FS. ▪ 11% FI. ▪ 12% FD. ▪ 26% FCS. ▪ 8% VFCS.	6.04	Relative low stress (3.3) on biota to provide adequate fast habitats (abundance and diversity) and maintained in good condition even under drought conditions: ▪ 10% FS. ▪ 8% FI. ▪ 33% FD. ▪ 27% FCS. ▪ 20% VFCS.
70%	2.30	Very low stress (2) on biota to support adequate fast habitats to maintain the biota in high PES: ▪ 10% FS. ▪ 9% FI. ▪ 21% FD. ▪ 28% FCS. ▪ 11% VFCS.	8.81	Low stress (2.5) on biota to ensure adequate fast habitats to maintain biota (especially for large semi-rheophilic species *L. natalensis*) in healthy state: ▪ 5.5% FS. ▪ 11% FI. ▪ 40% FD. ▪ 26% FCS. ▪ 24% VFCS.

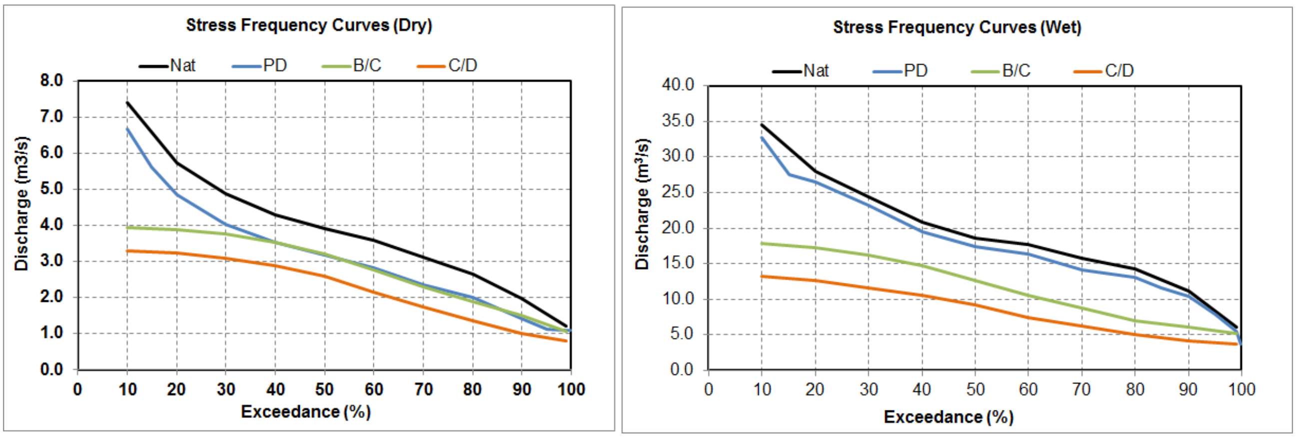

Figure 14.2 Mk_I_EWR2: Flow duration curves for the dry and wet season

14.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

Specified low flows will result in partial inundation of marginal zone sedges (*C. longus* and *J. effasus*) for 80% of the time in summer and 40% of the time in winter. The marginal zone is completely inundated from Jan to Apr for 40% of the time. Marginal zone woody vegetation (*S. mucronata*) is partially inundated from Dec to May for 40% of the time while lower zone woody vegetation (*S. guineense*) is never inundated. This highlights the importance of high flows for riparian vegetation. The site remains perennial with no zero flows. Confidence is high that specified flows (low and high) will maintain the ecological category of riparian vegetation.

14.5 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in Table 14.3and final high flow results are provided in Table 14.4.

Table 14.3 Mk_I_EWR2: Identification of instream functions addressed by the identified floods for riparian vegetation

Flood Class Flood Range (Peak in m^3/s)	Geomorphology and Riparian vegetation motivation	Fish flood functions						Macro-invertebrate 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 (40 – 60)	**Geomorphology:** These small events are important for flushing sands, for activating the bar, secondary channel and inundating the lower bench. Fine sediments would be flushed from the bed during these flows. **Riparian vegetation:**These events are required to flood the marginal and lower zones. Their primary role is to maintain habitat and species diversity due to disturbance, scouring and deposition. They will also reduce the presence of terrestrial species (terrestrialisation) as well as facilitate temporary removal of some alien species in these zones. The duration of inundation of three events over the growing season will also help maintain non-woody rather than woody vegetation.	√	√	√	√	√	√	√	√	√	√
CLASS II (80 - 100)	**Riparian vegetation:**Together with the smaller floods these events will comprise about five floods during the growing season. These events perform similar functions to the smaller floods but are particularly needed to facilitate recruiting opportunities for riparian woody species in the upper zone while also reducing the prevalence of woody vegetation in the marginal and lower zones.	√	√	√	√	√	√	√	√	√	√
CLASS III (160 - 200)	**Geomorphology:** At the upstream Mk_I_EWR1, this was the effective discharge flood class for sands. At this site, this flood is similarly important for channel scour and inundation of the upper bench. **Riparian vegetation:**This event results in some inundation to the current tree line of adult larger trees rather than just the sapling and juvenile bank. It is important to maintain the distinction between woody vegetation with high density and lower density, as well as scour some areas in the lower zones. It also provides recruiting opportunities higher on the bank.	√	√	√	√	√	√	√	√	√	√
CLASS IV (> 350)	**Geomorphology:**At the upstream Mk_I_EWR1, this was the effective discharge flood class for cobbles. At this site, this large flood will reset sedimentation and encroachment of the channel, and is responsible for inundating a high terrace at the site. **Riparian vegetation:** An infrequent large event needed to maintain (recruitment, reproduction, vigour) riparian woody species in the macro-channel bed and retard terrestrialisation of the same. It will also likely reduce the prevalence of some alien species, at least temporarily.	√	√	√	√	√	√	√	√	√	√

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

Table 14.4 Mk_I_EWR2: The recommended number of high flow events required

Flood Class (Peak in m^3/s)	Flood requirements*	Months	Daily Ave.	Duration (days)
CLASS I (40 – 60)	3	Nov – Apr	40	6
CLASS II (80 - 100)	2	Feb, Mar	75	7
CLASS III (160 - 2000)	1	Feb, Mar	150	7
CLASS IV (> 350)	1:3*	Summer	260	

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

14.6 EWR RESULTS

The results are provided as an EWR table (Table 14.5) and an EWR rule (Table 14.6 and Table 14.7). 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 14.8.

Table 14.5 Mk_I_EWR2: 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)	Daily average (m^3/s)	Duration (days)
Oct	1.974	2.757		
Nov	2.851	3.798	40	6
Dec	3.543	5.731	260	
Jan	5.115	7.432	40	6
Feb	5.991	8.732	75 150	7 7
Mar	8.862	10.488	75 150	7 7
Apr	6.501	8.150	40	6
May	4.270	5.834		
Jun	2.665	3.644		
Jul	1.646	2.670		
Aug	1.518	2.014		
Sep	1.551	2.374		

Table 14.6 Mk_I_EWR2: Assurance rules (m^3/s) for Instream PES and REC: B

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	5.009	4.879	4.811	4.437	3.694	3.267	2.757	2.370	1.974	1.621
Nov	7.135	7.026	6.761	6.339	5.453	4.584	3.798	3.162	2.851	2.306
Dec	11.700	11.658	11.005	9.676	8.087	6.668	5.731	4.423	3.543	2.864
Jan	15.849	15.550	14.363	13.078	10.623	8.938	7.432	5.869	5.115	4.340
Feb	17.674	17.113	16.125	14.590	12.461	10.483	8.732	6.948	5.991	5.149
Mar	17.714	17.035	16.190	15.392	13.700	12.026	10.488	9.152	8.862	8.014
Apr	15.357	14.700	14.442	13.419	11.666	9.549	8.150	6.731	6.501	5.901
May	9.983	9.776	9.726	9.270	8.215	7.039	5.834	4.673	4.270	2.935
Jun	6.294	6.193	5.747	5.618	4.998	4.375	3.644	2.965	2.665	1.698

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Jul	5.827	4.956	4.500	4.214	3.823	3.286	2.670	2.239	1.646	1.107
Aug	4.274	4.175	4.087	3.771	3.056	2.568	2.014	1.599	1.518	1.053
Sep	4.075	4.012	3.887	3.662	3.306	2.869	2.374	1.941	1.551	1.110

Table 14.7 Mk_I_EWR2: Assurance rules (m^3/s) for AEC: C

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	4.152	4.015	3.930	3.593	2.966	2.535	2.085	1.705	1.325	1.043
Nov	5.795	5.679	5.420	5.040	4.311	3.520	2.847	2.274	1.923	1.553
Dec	9.107	9.044	8.430	7.421	6.230	5.018	4.211	3.181	2.403	1.889
Jan	11.959	11.608	10.555	9.606	7.947	6.541	5.337	4.219	3.533	3.100
Feb	13.171	12.557	11.486	10.479	9.119	7.420	6.121	5.052	4.166	3.675
Mar	13.597	12.824	12.346	11.737	10.538	9.005	7.681	6.575	6.036	5.402
Apr	11.657	11.064	10.602	9.816	8.609	6.925	5.786	4.836	4.376	4.245
May	7.917	7.676	7.557	7.144	6.321	5.276	4.281	3.361	2.922	2.668
Jun	5.156	5.056	4.650	4.499	3.968	3.365	2.735	2.133	1.796	1.625
Jul	4.793	4.090	3.687	3.508	3.084	2.550	2.020	1.612	1.242	1.107
Aug	3.556	3.466	3.361	3.063	2.367	1.923	1.475	1.145	1.039	0.957
Sep	3.410	3.341	3.202	2.988	2.667	2.219	1.806	1.394	1.059	0.840

Table 14.8 Mk_I_EWR2: Summary of results as a percentage of the nMAR

EcoStatus	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
PES/REC: B	890.91	838.35	220.59	24.8	94.44	10.6	315.03	35.4
AEC: C			166.69	18.7	81.6	9.2	248.29	27.9

15 ECOCLASSIFICATION: MKOMAZI RIVER (MK_I_EWR3)

15.1 EIS RESULTS

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

- Unique instream biota: *L. natalensis*, other regional endemics and estuarine species.
- Species and taxon richness: Especially fish species and macro-invertebrates.
- Diversity of habitat types and features: Rapids, riffles, pools, overhanging vegetation and reeds.
- Migration route: Important for the migration of eel species in the system as well as *Macrobrachium*.
- Rare and endangered riparian species: *Crinum moorei* (Vulnerable),otters and red data bird species.
- Refugia and critical riparian habitat: Refugia for above rare and endangered riparian species.
- Diversity of riparian habitat types and features: Rocky vegetation, alluvial bars with backwater, reeds, variety of different vegetation structures, islands, high flow channels.
- Migration corridor: Important for bird species.

15.2 PRESENT ECOLOGICAL STATE

The PES reflects the changes in terms of the EC from reference conditions. The summarised PES information is provided in Table 15.1 and water quality and diatom information is provided in Appendix A and B respectively.

Table 15.1 Mk_I_EWR3: Present Ecological State

IHI Hydrology: PES: A/B, Confidence: 3
The nMAR is 1068.6 MCM and the pMAR is 983.2 MCM (92% of the nMAR). There is a 8% difference in MAR between observed and modeled present hydrology. The storage regulation in the catchment is low and the only dams in the area include a number of small farm dams in tributaries and a few instream dams. The upper part of the catchment is mainly a mountainous area, where nature reserves and the Sani Pass Tourism area are located. There is some agriculture and rural water use. The main activities in the catchment include forestry, cultivation, irrigation, some sugarcane, cattle farming and rural water use from low density rural settlements. The development of the upstream Mkomazi River Development Project (Smithfield Dam) will have a significant impact on the Mkomazi River and the effect of this future development will be observed at this EWR site. The abstraction for Sappi Saiccor takes place downstream of this EWR site. Due to land use, baseflow volumes have changed slightly from natural while floods have decreased.
Physico-chemical variables: PES: A/B, Confidence:3
Overgrazing and high population densities in the upper, middle and lower parts of the catchment have resulted in some increased sediment yields. However, no major water quality issues or hotspots were identified and the water quality of the Mkomazi is considered good.
Geomorphology: PES: B, Confidence: 4
This EWR site was surveyed in an earlier IFR study in 1997/8. The reach is a mixed bedrock/alluvial reach, one of the most easily observable for sedimentation effects. Comparisons with those earlier site photographs, as well as the historical aerial photographic record from 1937, 1967, 2002, 2005, 2009, 2011, 2013 and 2014, were available to document changes in the river. The aerial photographs document a dynamic (sections of braided river) reach, but with no directional planform change, suggesting that gross conditions are stable and the dynamics are natural. Similar river reaches have been documented in the Lowveld. There are no large dams in the catchment, and the expected small increase in sediment yield has not had a large impact on the river condition. Although the bars have increased in height and size since 1998, and vegetation encroachment at the site has been extensive, this is a natural process reset by very large floods (such as the 1986 Demonia floods), although it is likely accelerated by the enhanced stabilisation effects of alien vegetation. Cobbles, a few boulders, bedrock outcrops and coarse sand are present on the river bed in the active channel (DWA, 2013d; Rountree *et al*., 2001; 2004; unpublished site photographs from 1998 IFR study).
IHI Instream: PES: C, Confidence 3.1 IHI Riparian: PES: C, Confidence 3.8
Instream integrity is impacted by abstraction and instream weirs to a certain extent. There is some bed and bank modification due to siltation and water quality deterioration resulting in increased nutrients and algal growth.

Riparian integrity is impacted mainly by the presence of alien invasive vegetation. This results in substrate exposure and increased erosion. The structural changes in vegetation impact on the longitudinal and lateral connectivity.
Riparian vegetation: PES: D, Confidence: 3.1
The marginal zone consists of mixed cobble and alluvium and is dominated by non-woody vegetation, mainly reeds (*P. australis*), sedges and hydrophilic grasses (*Setaria* and *Paspalum*). The lower zone is similar to the marginal zone, but also with woody species *S. guineense*. Other dominants are *C. dives* and *C. dactylon*. The upper zone consists of mid-channel bars (dominated by *C. dactylon* and *S. guineense*) and terraces (mostly alien; Mexican sunflower, Bugweed and Peanut butter bush). The Macro Channel Bank is dominated by woody vegetation but is largely alien: *Ficus, Acacia, Melia, and Solanum.* A small backwater area exists and is dominated by *C. dives*. The predominant impact at the site is invasion by both woody and non-woody alien species with up to 80% cover in some areas.
Fish: PES: B, Confidence: 3
Based on the available fish distribution data and expected habitat composition, twenty-three indigenous fish species had a high to definite probability of occurrence under reference conditions. These included three freshwater eel species (*A. bengalensis labiata*, *A. marmorata, A. mossambica*), three cyprinids (*B. gurneyi, L. natalensis*and*B. viviparus*), oneclariid (*C. gariepinus*), four gobies (*A. aeneofuscus, G. giuris, G. callidus* and *Redigobius dewaali*) and four cichlids (*O. mossambicus, P. philander, T. rendalli and T. sparrmanii*). Various estuarine species also occur in the sub-quaternary reach and may frequent the EWR site at times (*A. berda, Gilchristella aestuaria,Liza macrolepis, Liza richhardsoni, Monodactylus argenteus, Myxus capensis, Mugil cephalus,* and *Monodactylus falciformis*). 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 slightly reduced FROC. The primary cause for reduced FROC include the loss of habitat (especially fast habitats) due to decreased flows (impacting especially on juvenile eels, *L. natalensis*), general habitat deterioration (impacting on species such as *B. gurneyi*, *L. natalensis*, *B. viviparus*) and water quality deterioration (especially *B. gurneyi* and *B. viviparus*). The estuarine species are expected to frequent the site at similar FROC than expected under natural conditions.
Macro-invertebrates: PES: B, Confidence: 3
A total of 30 SASS5 taxa were recorded during the field survey in June 2012 compared to 46 expected under natural conditions. Under these conditions, the SASS score was 215 with an ASPT of 7.1, which reflects a "Good" condition and is "Largely natural with few modifications". The suitability of the river for taxa with a preference for very high flows was moderate (63% of expected taxa), and for high flows was high (89% of expected taxa). Sensitive taxa included Prosopistomatidaeand Perlidae, and taxa expected but not recorded included Philopotamidaeand Oligoneuridae. The suitability of the river for taxa with a preference for SIC instream habitats was high (76% of expected taxa), and riverine vegetation was low (33% of expected taxa). The lower riverine vegetation scores can be ascribed to alien vegetation and previous disturbances. Sensitive taxa included Perlidae and Pyralidae; and taxa expected but not recorded included Hydroptilidae. The suitability of the river for taxa with a high requirement for unmodified physico-chemical conditions was very high (86% of expected taxa) while there was an occurrence of 64% of the expected taxa with a preference for moderate water quality. Adverse conditions that might influence the water quality could be sedimentation. Taxa expected but not recorded included Oligoneuridae.

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 and alien invasive vegetation impact the riparian zone and has resulted in substrate exposure and increased erosion. The structural changes in vegetation impact on the longitudinal and lateral connectivity.

15.3 RECOMMENDED ECOLOGICAL CATEGORY

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and attainability there-of. The EIS was MODERATE and the REC was therefore set to maintain the PES. Due to non-flow related impacts on riparian vegetation, the EWR was set for the instream EC of a B.

15.4 ALTERNATIVE ECOLOGICAL CATEGORY

The scenario included key driver change associated with a new upstream dam which would result in:

- Decreased base flows and big floods.
- More islands, fewer secondary channels and less quality instream habitats occur.
- Increased woody vegetation on islands.
- Loss of non-woody vegetation as it will be shaded out by the increased woody vegetation.

- Increased marginal vegetation encroachment.

Each component was adjusted to indicate the metrics that will react to the scenarios. The changes in the rule based models for the AEC are provided electronically and summarised inTable 15.2.

Table 15.2 Mk_I_EWR3: Alternative Ecological Category

Physico-chemical variables: AEC: B
Impacts of the upstream dam will be reduced due to the increased distance from the dam. Some increases in sedimentation levels may be expected.
Geomorphology: AEC: B/C
At this site, some reduction of scour of the bed (and reduced scour of riffles) would be associated with the reduced floods. Vegetated islands may become more stable, and some secondary channels may be abandoned, due to the reduced floods. These impacts would be small and are only expected to result in a half category decline in the PES of geomorphology.
Riparian vegetation: AEC: D
As with Mk_I_EWR2, reducing flooding disturbance will promote the rate of increase of woody cover along higher-level lateral bars and islands. Some of the increase in woody cover will be by terrestrial species or alien perennial species. Some of this shading effect will reduce localised non-woody cover or change the species composition. Reduced base flows, together with increased sediment deposition are likely to result in increases in non-woody vegetation in the marginal and lower zones, particularly as the marginal zone encroaches towards the active channel.
Fish: AEC: C
It is estimated that under this scenario the fish assemblage will be reduced to a slightly lower ecological category C. Most of the species are not expected to be influenced notably, with the only significant impact expected due to reduced baseflow leading to a loss in habitat quality (impacting on species such as *L. natalensis* and a lesser degree *B. viviparus*).
Macro-invertebrates: AEC: C
None of the taxa are expected to disappear, but abundances will change; lower sensitive species numbers and higher tolerant species numbers. Atotal of 30 SASS5 taxa were recorded during the field survey in June 2012 compared to 46 expected under natural conditions. Under these conditions, the SASS score will be 215 with an ASPT of 7.1, which reflects a “Good” condition and is “Largely natural with few modifications. The lower MIRAI scores related to flows can be attributed to the expected decreased flows and floods due to the proposed new dam. The lower MIRAI scores related to habitat can be attributed to the encroachment of alien plants woody vegetation, more islands and fewer secondary channels. The lower MIRAI scores related to water quality can be attributed to the change in water temperature (decreased flows).

15.5 ECOCLASSIFICATION SUMMARY

The EcoClassification results are summarised in Table 15.3.

Table 15.3 Mk_I_EWR3: Summary of EcoClassification results

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

16 EWR REQUIREMENTS: MKOMAZI RIVER (MK_I_EWR3)

16.1 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 16.1 and a description of the habitat associated with the stress is provided in Table 16.1.

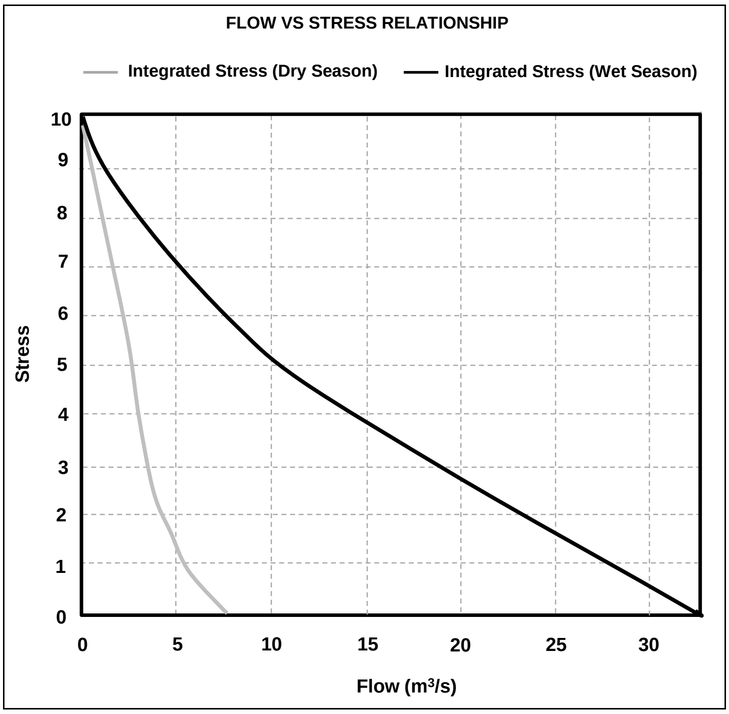

Figure 16.1 Mk_I_EWR3: Stress index

Table 16.1 Mk_I_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
1	5.25	Adequate fast habitats to ensure limited stress for Perlidae: ▪ 3% FS. ▪ 3% FI. ▪ 21% FD. ▪ 16% FCS. ▪ 3% VFCS.	28.12	Habitat very similar to under natural conditions with limited stress expected. Critical habitat for indicator species (*L. natalensis*) are as follows: ▪ 4 % FS ▪ 5% FI ▪ 62% FD
5	2.79	Although fast habitats are largely reduced it is adequate to maintain biota with moderate stress: ▪ 2%FS. ▪ 3%FI. ▪ 9%FD. ▪ 7%FCS. ▪ 1%VFCS.	10.61	Approximately 50% decrease in critical habitats of indicator species. Habitat composition include approximately: ▪ 10%FS. ▪ 4%FI. ▪ 28%FD.
8	1.07	Very limited fast habitat resulting in high stress on instream biota: ▪ 1%FS. ▪ 1%FI. ▪ 1%FD.	3.29	Only 14% suitable habitats .Very limited breeding habitat and longitudinal connectivity ▪ 2%FS. ▪ 3%FI.

Stress	Dry season		Wet season	
	Flow (m^3/s)	Habitat and stress description	Flow (m^3/s)	Habitat and stress description
		▪ 2% FCS. ▪ No VFCS (0%).		▪ 9%FD.

16.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as February and August. Droughts are set at 90% exceedance (flow) and 10% exceedance (stress). Maintenance flows are set at 30% exceedance (flow) and at 70% exceedance (stress).

16.3 INSTREAM BIOTA REQUIREMENTS

The required stress to maintain the instream PES of a B was determined by specialists and descriptions of key stress points (Table 16.2) are provided below. The requirements are illustrated as flow duration curves in Figure 16.2.

Table 16.2 Mk_I_EWR3: Stress requirements and habitat and instream biota description

Instream PES: B	Dry season		Wet season	
Percentile	Flow (m^3/s)	Description	Flow (m^3/s)	Description
90% (drought)	1.59	Biota will be notably stressed (7) but flow should be adequate to allow survival and ensure maintenance in PES: ▪ 2% FS. ▪ 3% FI. ▪ 2% FD. ▪ 3% FCS. ▪ 0% VFCS.	7.8	Relative high stress (6) but adequate fast habitats (abundance and diversity) will be maintained even under drought conditions: ▪ 9% FS. ▪ 3% FI. ▪ 27% FD. ▪ 17% FCS. ▪ 3% VFCS.
70%	2.57	Moderate stress (5) on biota but adequate fast habitats to maintain the biota in PES: ▪ 2% FS. ▪ 3% FI. ▪ 10% FD. ▪ 5% FCS. ▪ 0% VFCS.	9.92	Moderate stress (5) on biota but adequate fast habitats to maintain biota (especially for large semi-rheophilic species *L. natalensis and*) in healthy state: ▪ 11% FS. ▪ 7% FI. ▪ 30% FD. ▪ 19% FCS. ▪ 5% VFCS.

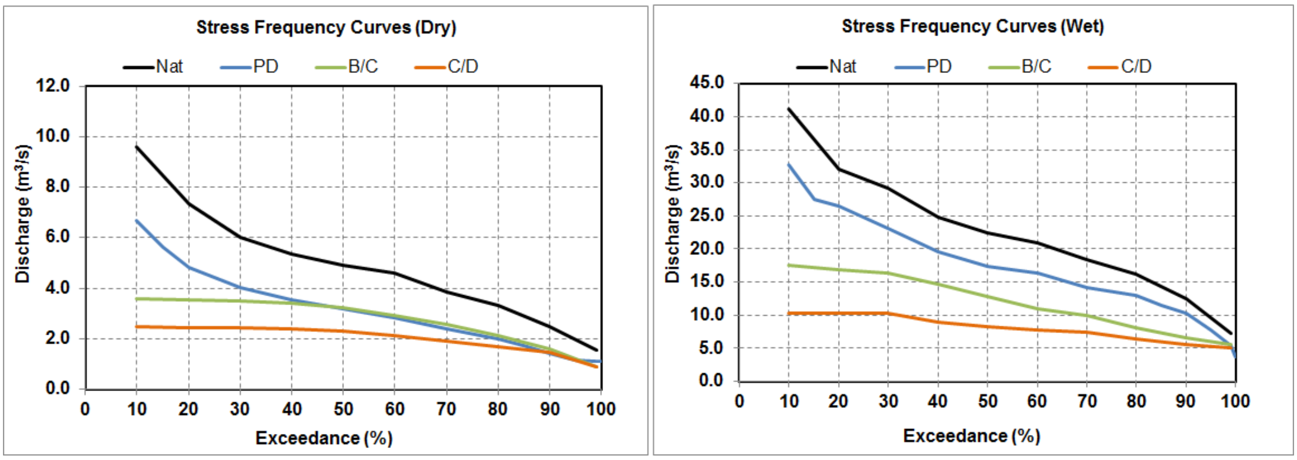

Figure 16.2 Mk_I_EWR3: Flow duration curves for the dry and wet season

16.4 VERIFICATION OF LOW FLOWS: RIPARIAN VEGETATION

P. australis in pool areas remains partially inundated throughout the year all of the time. Marginal zone sedges and grasses (*S.sphacelata, C. longus* and *J. effasus*) are partially inundated for 80-90% of the time in summer and for a small portion of time in winter but not throughout winter. Lower zone woody vegetation (*S. guineense*) is partially inundated for 40-50% of the time from January to April and from February to March respectively. Seasonally active riparian vegetation such as *L.octovalvis* is not inundated by specified low flows, highlighting the importance of high flows for riparian vegetation. The site remains perennial with no zero flows. Confidence is high that low flows, together with high flows, will maintain the ecological category of riparian vegetation.

16.5 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in Table 16.3and final high flow results are provided in Table16.4.

Table 16.3 Mk_I_EWR3: Identification of instream functions addressed by the identified floods for riparian vegetation

Flood Class Flood Range (Peak in m^3/s)	Geomorphology and Riparian vegetation motivation	Fish flood functions: Migration cues & spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Macro-invertebrate flood functions: Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
CLASS I (40 - 60)	**Geomorphology:** These small events are important for flushing sands, for activating and inundating lower sedimentary bars and flushing the secondary channels. Fine sediments would be flushed off the predominantly cobble the bed during these flows. **Riparian vegetation:** These events are required to flood the marginal and lower zones. Their primary role is to maintain habitat and species diversity due to disturbance, scouring and deposition. They will also reduce the presence of terrestrial species (terrestrialisation) as well as facilitate temporary removal of some alien species in these zones. The duration of inundation of 4 events over the growing season will also help maintain non-woody rather than woody vegetation.	√	√	√	√	√	√	√	√	√	√
CLASS II (80 - 100)	**Riparian vegetation:** Together with the smaller floods these events will comprise about six floods during the growing season. These events perform similar functions to the smaller floods but are particularly needed to facilitate recruiting opportunities for riparian woody species in the upper zone while also reducing the prevalence of woody vegetation in the marginal and lower zones.	√	√	√	√	√	√	√	√	√	√
CLASS III (160-200)	**Geomorphology:** At the upstream Mk_I_ EWR1, this was the effective discharge flood class for sands. At this site, this flood is similarly important for channel scour and inundation of a small terrace. **Riparian vegetation:** This event results in some inundation to the current tree line of adult larger trees rather than just the sapling and juvenile bank. It is important to maintain the distinction between woody vegetation with high density and lower density, as well as scour some areas in the lower zones. It also provides recruiting opportunities higher on the bank.	√	√	√	√	√	√	√	√	√	√
CLASS IV (>350)	**Geomorphology:**At the upstream Mk_I_EWR1, this was the effective discharge flood class for cobbles. At this site, this large flood should be important for keeping sand accumulations in check and may activate some of the cobbles at the site. **Riparian vegetation:** An infrequent large event needed to maintain (recruitment, reproduction, vigour) riparian woody species in the macro-channel bed and retard terrestrialisation of the same. It will also likely reduce the prevalence of some alien species, at least temporarily.	√	√	√	√	√	√	√	√	√	√

The availability of high flows was verified using the observed data at gauge U1H009 (downstream of the EWR site).

Table 16.4 Mk_I_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(40 - 60)	4	Nov – Apr	45	6
CLASS II(80 - 100)	2	Feb, Mar	75	7
CLASS III(160-200)	1	Feb, Mar	150	8
CLASS IV(>350)	1:3*	Summer	260	

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

16.6 EWR RESULTS

The results are provided as an EWR table (Table 16.5) and an EWR rule (Table 16.6 and Table 16.7). 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 16.8.

Table 16.5 Mk_I_EWR3: 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)	Daily average (m^3/s)	Duration (days)
Oct	2.249	3.076		
Nov	3.198	4.100	45	6
Dec	3.909	6.048	45 260	6
Jan	5.557	7.905	45	6
Feb	6.606	9.845	75 150	7 8
Mar	7.796	9.922	75 150	7 8
Apr	6.645	8.915	45	6
May	4.736	6.412		
Jun	3.009	4.063		
Jul	1.659	2.980		
Aug	1.420	2.341		
Sep	1.647	2.651		

Table 16.6 Mk_I_EWR3: Assurance rules (m^3/s)for Instream PES and REC: B

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	4.690	4.536	4.518	4.174	3.733	3.321	3.076	2.693	2.249	1.792
Nov	6.793	6.602	6.517	6.194	5.359	4.590	4.100	3.504	3.198	2.514
Dec	11.725	11.552	10.875	9.185	8.084	6.946	6.048	4.886	3.909	3.178
Jan	16.420	15.662	14.774	12.864	10.669	9.053	7.905	6.548	5.557	4.662
Feb	17.469	16.701	16.207	14.526	12.629	10.951	9.845	8.090	6.606	5.554
Mar	18.886	18.008	16.681	14.962	13.192	11.416	9.922	8.760	7.796	6.961
Apr	15.588	15.347	15.073	13.603	11.844	10.067	8.915	7.780	6.645	6.092
May	9.926	9.926	9.833	9.173	8.443	7.235	6.412	5.385	4.736	3.120
Jun	6.161	5.976	5.599	5.391	5.110	4.498	4.063	3.386	3.009	1.832

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Jul	5.411	4.794	4.252	4.109	3.862	3.390	2.980	2.471	1.659	1.019
Aug	4.071	3.992	3.821	3.586	3.122	2.666	2.341	1.840	1.420	0.895
Sep	3.685	3.656	3.604	3.503	3.323	3.037	2.651	2.213	1.647	0.899

Table 16.7 Mk_I_EWR3: Assurance rules (m^3/s)for Instream PES and REC: B

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	3.179	3.116	3.106	2.905	2.643	2.409	2.314	2.134	1.903	1.650
Nov	4.436	4.371	4.348	4.209	3.746	3.313	3.082	2.781	2.706	2.391
Dec	7.096	7.078	6.810	6.027	5.521	4.962	4.536	3.872	3.309	2.849
Jan	9.281	9.049	8.774	8.069	7.113	6.401	5.920	5.196	4.705	4.216
Feb	10.213	10.213	10.123	8.918	8.249	7.668	7.366	6.421	5.589	5.029
Mar	10.309	10.051	9.661	9.157	8.577	7.975	7.421	6.967	6.591	6.249
Apr	8.976	8.976	8.922	8.461	7.800	7.083	6.672	6.176	5.630	5.542
May	6.278	6.278	6.254	6.022	5.750	5.163	4.808	4.273	4.076	3.120
Jun	4.074	3.985	3.789	3.701	3.580	3.247	3.053	2.685	2.580	1.832
Jul	3.608	3.260	2.934	2.863	2.731	2.458	2.241	1.991	1.659	1.019
Aug	2.801	2.759	2.654	2.504	2.140	1.900	1.755	1.592	1.420	0.895
Sep	2.552	2.539	2.512	2.457	2.359	2.203	1.993	1.754	1.532	0.899

Table 16.8 Mk_I_EWR3: Summary of results as a percentage of the nMAR

EcoStatus	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
PES/REC instream: B	1068.6	983.23	223.42	20.9	104.6	9.8	328.02	30.7
AEC: C			151.2	14.2	90.35	8.4	241.55	22.6

17 CONCLUSIONS AND RECOMMENDATIONS

17.1 ECOCLASSIFICATION

The EcoClassification results are summarised below in Table 17.1.

Table 17.1 EcoClassification Results summary

MG_I_EWR2: uMNGENI RIVER

EIS: MODERATE
Highest scoring metrics were diversity of habitat types and migration route. Rare and endangered riparian species occur and intolerant vegetation species are present.

PES: C/D

- Decreased base flows and floods due to Midmar Dam resulting in a loss of flow diversity.
- Alien invasive vegetation, grazing pressure and species composition change in the riparian zone has led to a general loss of connectivity and resulted in bank modification.
- The decrease in baseflows has impacted on habitat availability and abundance.
- Deteriorated water quality impacts (Howick and sediment dam releases has seriously impacted on the fish frequency of occurrence.

REC: C/D
The EIS was moderate and the REC is set to maintain the PES. The fish component is in an unacceptable condition and has to improve to a D EC. This improvement will not require changes in flow.

Component	PES & REC
IHI Hydrology	C/D
Physico chemical	C/D
Geomorphology	D
Fish	E* (D)
Invertebrates	C
Instream	D
Riparian vegetation	C
EcoStatus	C
Instream IHI	D
Riparian IHI	C
EIS	MODERATE
*** Fish to improve**	

MG_I_EWR5: uMNGENI RIVER

- **EIS: MODERATE**
- Highest scoring metrics were diversity of habitat types and features, taxon richness and rare and endangered riparian species.

- **PES: D**
- Decreased baseflows and floods due to upstream dams and general landuse in the upper catchment.
- Reduced habitat abundance.
- Deteriorated water quality (uMnsunduze inflows etc. and increased sedimentation).
- Alien invasive vegetation species, vegetation removal and sand mining leading to a general loss of connectivity and bank modification.
- Presence of two predatory alien fish species in the reach.

- **REC: D**

EIS was Moderate and the REC was therefore set to maintain the PES.

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

MK_I_EWR1: MKOMAZI RIVER

EIS: MODERATE
Highest scoring metrics were unique instream biota, species intolerant to flow, diversity of habitat types and features and rare and endangered riparian species.

PES: C
- Overgrazing and alien invasive vegetation in the riparian zones have led to substrate exposure and increased erosion.
- Increased sedimentation has resulted in higher turbidity.
- Migration barriers and alien fish species.

REC: C
- EIS was Moderate and the REC was therefore to maintain the PES. Due to non-flow related impacts on riparian vegetation, the EWR was set for the instream EC of a B/C.

AEC down: D
- The scenario is based on the impacts of a possible upstream dam which will result in:
- Decreased base flows and floods from a dam.
- Some change in water temperature.
- Erosion of the marginal zone due to scour.
- Decreased fines within the system.
- Increased alien vegetation due to decreased floods.

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

MK_I_EWR2: MKOMAZI RIVER

EIS: HIGH
Highest scoring metrics were unique instream biota, species intolerant to flow, diversity of habitat types, migration route, rare and endangered riparian species, riparian species intolerant to flow and migration corridor for birds.

PES: B
- Increased catchment erosion and alien invasive vegetation in the upper riparian zone leading to substrate exposure.
- Alien predatory fish species.

REC: B
The EIS was High and although an improvement is normally required most components are already in a B EC except for fish which is impacted by alien species. The REC was therefore set to maintain the PES.

AEC down: C
The scenario is based on the impacts of a possible upstream dam which will result in:

- Decreased base flows and floods.
- Some change in water temperature and decreased turbidity.
- Encroachment of non-woody vegetation and more reeds in the marginal zone.
- Reduced scour resulting in increased sedimentation.
- Less mobile beds.
- Increased alien vegetation due to decreased floods.

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

MK_I_EWR3: MKOMAZI RIVER

EIS: MODERATE
- Highest scoring metrics were unique instream biota, species intolerant to flow, diversity of habitat types and features and rare and endangered riparian species.

PES: C
- Overgrazing, trampling and alien invasive vegetation impact the riparian zone and has resulted in substrate exposure and increased erosion.
- The structural changes in vegetation impact on longitudinal and lateral connectivity

REC: C
- The EIS was Moderate and the REC was therefore set to maintain the PES. Due to non-flow related impacts on riparian vegetation, the EWR was set for the instream EC of a B.

AEC down: D
- The scenario is based on the impacts of a possible upstream dam which will result in:
- Decreased base flows and large floods.
- More islands, fewer secondary channels and less quality instream habitats.
- Increased woody vegetation on islands.
- Loss of non-woody vegetation as it will be out-shaded by the increased woody vegetation.
- Increased marginal vegetation encroachment.

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

MV_I_EWR1: HEYNESPRUIT

EIS: MODERATE
Unique fish occur (*B. natalensis* – regional endemic) and instream habitat sensitive to flow changes. Rare and endangered riparian species are present and are intolerant.

PES: C
- Decreased base flows impact to some extent on habitat availability and abundance.
- Deteriorated water quality due to releases from the WWTW resulting in high nutrient levels as well as the presence of toxics.
- High occurrence of alien vegetation species and the presence of three predatory alien fish species.
- General loss of connectivity and bank modification.

REC: C
The EIS was Moderate and therefore the REC was set to maintain the PES.

AEC down: D
- The scenario included further decreased baseflows and floods:
- Increased sedimentation of riffles and fine accumulation in pools.
- Vegetation species composition change with a higher occurrence of grasses and shrubs, and a decrease in sedges.
- Increased nutrients.

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

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<tr><th colspan="2">MV_I_EWR2 MVOTI RIVER</th></tr>
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EIS: MODERATE
Unique instream fish biota occur (regional freshwater endemics and estuarine fish). There is a diversity of habitat types and the reach is an important migration route for eels. Rare and endangered riparian species are present.

PES: C
▪ Decreased base flows have impacted to some extent on habitat availability and abundance.
▪ Deteriorated water quality.
▪ Catchment erosion.
▪ Two predatory alien fish species.
▪ Alien invasive vegetation in the riparian zones along with wood harvesting and clearance has led to a general loss of connectivity and bank modification.

REC: B
The EIS is Moderate, however the instream component of the EIS is High, and improvement can be achieved by non-flow related measures. The REC will therefore indicate the improvement, but an EWR for improved flows will not be set.

AEC down: D
The scenario is based on the impacts of a possible upstream dam which will result in:
▪ Increased sedimentation of riffles and fines accumulation in pools.
▪ Vegetation species composition change with a higher occurrence of grasses and shrubs, and a decrease in sedges.
▪ Increased nutrients.

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<table>
<tr><th>Component</th><th>PES</th><th>REC</th><th>AEC↓</th></tr>
<tr><td>IHI Hydrology</td><td>B/C</td><td></td><td></td></tr>
<tr><td>Physico chemical</td><td>C</td><td>C</td><td>D</td></tr>
<tr><td>Geomorphology</td><td>C</td><td>C</td><td>D</td></tr>
<tr><td>Fish</td><td>B/C</td><td>B</td><td>C</td></tr>
<tr><td>Invertebrates</td><td>B/C</td><td>B</td><td>C/D</td></tr>
<tr><td>Instream</td><td>B/C</td><td>B</td><td>C/D</td></tr>
<tr><td>Riparian vegetation</td><td>C/D</td><td>C/D</td><td>D</td></tr>
<tr><td>EcoStatus</td><td>C</td><td>B</td><td>C/D</td></tr>
<tr><td>Instream IHI</td><td>C</td><td colspan="2" rowspan="2"></td></tr>
<tr><td>Riparian IHI</td><td>C</td></tr>
<tr><td>EIS</td><td colspan="3">MODERATE</td></tr>
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The confidence in the EcoClassification process is provided below (Table 17.2) 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 17.2 Confidence in EcoClassification

EWR site	Data availability								EcoClassification								
	Hydrology	Water Quality	Geomorphology	Fish	Inverts	Vegetation	Average	Median	Hydrology	Water Quality	Geomorphology	IHI	Fish	Inverts	Vegetation	Average	Median
Mv_I_EWR1	2.0	3.5	4.0	2.0	3.0	3.0	2.9	3.0	2.0	4.0	4.0	3.4	3.0	3.0	3.3	3.2	3.3
Mv_I_EWR2	1.5	2.5	4.0	2.0	3.0	3.0	2.7	2.8	1.0	3.5	3.5	3.1	3.0	3.0	3.1	2.9	3.1
Mg_I_EWR2	3.0	3.0	4.0	2.0	3.0	3.0	3.0	3.0	3.0	4.0	3.5	3.6	2.5	3.0	2.9	3.2	3.0
Mg_I_EWR5	3.0	3.5	4.0	2.0	3.0	3.0	3.1	3.0	3.0	3.5	3.5	3.4	3.0	3.0	3.1	3.2	3.1
Mk_I_EWR1	3.0	3.5	4.0	2.0	3.0	3.0	3.1	3.0	3.0	4.0	4.0	3.6	3.0	3.0	2.9	3.4	3.0
Mk_I_EWR2	3.0	2.5	4.0	2.0	3.0	3.0	2.9	3.0	3.0	3.5	4.0	3.6	3.0	3.0	2.9	3.3	3.0
Mk_I_EWR3	3.0	3.5	4.0	2.0	3.0	3.0	3.1	3.0	3.0	3.0	4.0	3.4	3.0	3.0	3.1	3.2	3.0

The confidence in data availability and EcoClassification was Moderate at all the EWR sites.

17.2 ECOLOGICAL WATER REQUIREMENTS

The final flow requirements are expressed as a percentage of the nMAR in Table 17.3.

Table 17.3 Summary of results as a percentage of the nMAR

EWR site	Ecological Category	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%)	High flows (MCM)	High flows (%)	Total flows (MCM)	Total (%)
Mv_I_EWR1	PES/REC: C	17.36	7.08	3.16	18.2	1.69	9.7	4.85	27.9
	AEC: D			2.26	13	1.6	9.2	3.85	22.2
Mv_I_EWR2	PES/REC instream: B/C	273.96	168.84	48.3	17.6	19.4	7.1	67.7	24.7
	AEC instream: C/D			33.4	12.2	17.6	6.4	51	18.6
Mk_I_EWR1	PES/REC instream: B/C	683.17	660.72	171.78	25.1	67.31	9.9	239.09	35
	AEC: C/D			88.96	13	57.57	8.4	146.53	21.4
Mk_I_EWR2	PES/REC: B	890.91	838.35	220.59	24.8	94.44	10.6	315.03	35.4
	AEC: C			166.69	18.7	81.6	9.2	248.29	27.9
Mk_I_EWR3	PES/REC instream: B	1068.6	983.23	223.42	20.9	104.6	9.8	328.02	30.7
	AEC: C			151.2	14.2	90.35	8.4	241.55	22.6
Mg_I_EWR2	PES/REC: C/D (RDRM C)	228.19	105.4	33.5	14.7	12.1	5.3	45.6	20
Mg_I_EWR5	PES/REC instream:C/D	583.7	245.3	133.57	22.9	17.03	2.9	150.6	25.8

17.2.1 Confidence

17.2.2 Confidence in low flows

The question the confidence assessment should answer is the following:

> 'How confident are you that the low flow (with the associated high flows) recommended will achieve the EC?' considering the quality of data.

Table 17.4 provides the confidence in the low flow requirements of the biotic components (fish and macroinvertebrates). The final average confidence is representative of these requirements.

Table 17.4 Low flow confidence ratings for biotic responses

EWR site	Fish	Inverts	Comment	Overall confidence
Mv_I_EWR1	3	3	**Fish:** These flows should be adequate to attain the specific EC for fish. No rheophilic species is present and hence the rheophilic invertebrate used as dry season indicator will ensure adequate flows for fish. Although still limited, the fast habitats in the wet season should be adequate for the large semi-rheophilic *L. natalensis* (used as the indicator guild) to ensure the maintenance of the instream biota in the PES. **Inverts:** Although relatively limited, adequate fast habitats should be available during wet season (as determined for semi-rheophilic fish) and dry season to maintain the indicator taxon and the invertebrate assemblage as a whole in the PES.	**3**
Mv_I_EWR2	4	4	**Fish:** These flows should be adequate to attain the specific EC for fish. No rheophilic species is present and hence the rheophilic invertebrate used as dry season indicator will ensure adequate flows for fish. Adequate fast habitats will be available during the wet season for the large semi-rheophilic *L. natalensis* (used as the indicator guild) to ensure the maintenance of the instream biota in the PES. **Inverts:** Adequate fast habitats should be available during wet season (as determined for semi-rheophilic fish) and dry season to maintain the indicator taxon and the invertebrate assemblage as a whole in the PES.	**4**
Mg_I_EWR2	3	3.5	**Fish:** These flows should be adequate to attain the specific EC for fish. The dry season flows adequate to ensure the survival of the small rheophilic fish species (*A. natalensis*) while adequate fast habitats will be available during the wet season for all life processes of the large semi-rheophilic *L. natalensis* (used as the indicator guild) to ensure the maintenance of the instream biota in the PES. **Inverts:** Dry season flows required by the small rheophilic fish species and wet season flows driven by the requirements of a large semi-rheophilic fish species should be adequate to maintain the invertebrate assemblage in its PES.	**3.3**
Mg_I_EWR5	5	5	**Fish:** These flows should be more than adequate to attain the specific EC for fish. The dry season flows adequate to ensure the survival of the small rheophilic fish species (*A. natalensis*) while adequate fast habitats will be available during the wet season for all life processes of the large semi-rheophilic *L. natalensis* (used as the indicator guild) to ensure the maintenance of the instream biota in the PES. **Inverts:** Dry season flows required by the small rheophilic fish species and wet season flows driven by the requirements of a large semi-rheophilic fish species should be adequate to maintain the invertebrate assemblage in its PES.	**5**
Mk_I_EWR1	4	4.5	**Fish:** These flows should be adequate to attain the specific EC for fish. The dry season flows adequate to ensure the survival of the small rheophilic fish species (*A. natalensis*) while adequate fast habitats will be available during the wet season for all life processes of the large semi-rheophilic *L. natalensis* (used as the indicator guild) to ensure the maintenance of the instream biota in the PES. **Inverts:** Dry season flows required by the small rheophilic fish species and wet season flows driven by the requirements of a large semi-rheophilic fish species should be adequate to maintain the invertebrate assemblage in its PES.	**4.3**
Mk_I_EWR2	4	4.5	**Fish:** These flows should be adequate to attain the specific EC for fish. The dry season flows adequate to ensure the survival of the small rheophilic fish species (*A. natalensis*) while adequate fast habitats will be available during the wet season for all life processes of the large semi-rheophilic *L. natalensis* (used as the indicator guild) to ensure the maintenance of the instream biota in the PES. **Inverts:** Dry season flows required by the small rheophilic fish species and wet season flows driven by the requirements of a large semi-rheophilic fish species should be adequate to maintain the invertebrate assemblage in its PES.	**4.3**
Mk_I_EWR3	4	4	**Fish:** These flows should be adequate to attain the specific EC for fish. No rheophilic species is present and hence the rheophilic invertebrate used as dry season indicator will ensure adequate flows for fish. Adequate fast habitats will be available during the wet season for the large semi-rheophilic *L. natalensis* (used as the indicator guild) to ensure the maintenance of the instream biota in the PES. **Inverts:** Adequate fast habitats should be available during wet season (as determined for semi-rheophilic fish) and dry season to maintain the indicator taxon and the invertebrate assemblage as a whole in the PES.	**4**

17.2.3 Confidence in high flows

The question the confidence assessment should answer is the following:
'How confident are you that the high flow (with the associated low flows) recommended will achieve the EC?'

To determine the confidence, one should consider:

- The quality of available data; and
- whether the vegetation requirement was increased to cater for a larger requirement recommended for geomorphology. Then the riparian vegetation confidence could be high as more water is provided.

The high flow confidence (Table 17.5) represents an average of the riparian vegetation and geomorphology confidence as these two components determine the flood requirements.

Table 17.5 Confidence in recommended high flows

EWR site	Fish	Inverts	Riparian vegetation	Geomorphology	Comment	Overall confidence
Mv_I_EWR1	4	4	2.5	2.5	**Fish:**These flows should be adequate to attain the specific EC for fish. No rheophilic species is present and hence the rheophilic invertebrate used as dry season indicator will ensure adequate flows for fish. Although still limited, the fast habitats in the wet season should be adequate for the large semi-rheophilic *L. natalensis* (used as the indicator guild) to ensure the maintenance of the instream biota in the PES.	2.5
					Inverts: Although relatively limited, adequate fast habitats should be available during wet season (as determined for semi-rheophilic fish) and dry season to maintain the indicator taxon and the invertebrate assemblage as a whole in the PES.	
					Riparian vegetation: The presence of obligate riparian indicators was low at the cross section and was influenced by a large seep wetland on the LB which would provide inflow from excess seepage, thus limiting the direct usefulness of existing indicators to upstream flows. Nevertheless the channel morphology is uncomplicated with a clear shrub zone, improving the estimation of floods related to the woody component. Since the site occurs within a high rainfall grassland there is less distinction between the riparian zone and the terrestrial upland with respect to species composition and there are also no gradient cues to aid riparian delineation, making it difficult to estimate large infrequent floods. Nevertheless confidence that estimated floods will maintain the PES of the riparian vegetation is moderate, assuming that non-flow related impacts remains unchanged and that base flows are sufficient.	
					Geomorphology: Available data is limited – there is no flow gauge record for the catchment, and the morphological cues at the site are weak. However these cues did correspond well with the vegetation cues at the site, allowing for moderate confidence.	
Mv_I_EWR2	4	4	3	2.5	**Fish:**These flows should be adequate to attain the specific EC for fish. No rheophilic species is present and hence the rheophilic invertebrate used as dry season indicator will ensure adequate flows for fish. Adequate fast habitats will be available during the wet season for the large semi-rheophilic *L. natalensis* (used as the indicator guild) to ensure the maintenance of the instream biota in the PES.	2.75
					Inverts: Adequate fast habitats should be available during wet season (as determined for semi-rheophilic fish) and dry season to maintain the indicator taxon and the invertebrate assemblage as a whole in the PES.	

EWR site	Fish	Inverts	Riparian vegetation	Geomorphology	Comment	Overall confidence
					Riparian vegetation: Although disturbance at the site was high, there were sufficient riparian zone indicators within each of the sub-zones. High confidence estimations of floods were therefore possible using hydraulic lookup tables, but there were no hydrological data to verify whether estimated requirements were realistic in terms of available present day flows. The estimated requirement covers a range of floods and also considers channel morphology associated with vegetation distribution within the riparian zone. Confidence that the flooding regime will maintain the PES of the riparian vegetation is moderate and assumes that base flows are sufficient and that non-flow related impacts remain unchanged.	
					Geomorphology: Available data is very limited – there is no flow gauge record for the catchment to enable sediment transport analyses to be undertaken. However flood requirements determined from the morphological cues at the site did correspond well with the vegetation flood requirements, allowing for moderate confidence.	
Mg_I_EWR2	4	4	3.5	n/a	**Fish:** These flows should be adequate to attain the specific EC for fish. The dry season flows adequate to ensure the survival of the small rheophilic fish species (*A. natalensis*) while adequate fast habitats will be available during the wet season for all life processes of the large semi-rheophilic *L. natalensis* (used as the indicator guild) to ensure the maintenance of the instream biota in the PES. **Inverts:**Dry season flows required by the small rheophilic fish species and wet season flows driven by the requirements of a large semi-rheophilic fish species should be adequate to maintain the invertebrate assemblage in its PES. **Riparian vegetation:** It is clear that flow has been regulated at this site since the vegetation zonation is distinct. This usually indicates that species have aligned themselves along the moisture gradient (predominant determinant) according to competitive interactions since flooding disturbance has been reduced and heterogeneity has been largely lost. Although the high flows requested are to maintain this altered state, there were an abundance of riparian indicators at the site as well as a recent hydraulic lookup table. Confidence that high flows will maintain the PES (predominantly flow related) is moderate to high and assumes that zero flows and non-flow related impacts remain unchanged. **Geomorphology:** Confidences are notapplicable as no flood flows for this site were requested. The site is located between the Midmar and Albert Falls Dam and almost all sand and gravel has been winnowed out of the site, creating an armoured cobble/boulder bed river. No flood flows for this site were therefore requested, since the reach is already sediment starved and large floods would merely accelerate sediment loss and a move away from natural habitat types.	3.5
Mg_I_EWR5	4	4	3	2.5	**Fish:**These flows should be more than adequate to attain the specific EC for fish. The dry season flows adequate to ensure the survival of the small rheophilic fish species (*A. natalensis*) while adequate fast habitats will be available during the wet season for all life processes of the large semi-rheophilic *L. natalensis* (used as the indicator guild) to ensure the maintenance of the instream biota in the PES. **Inverts:**Dry season flows required by the small rheophilic fish species and wet season flows driven by the requirements of a large semi-rheophilic fish species should be adequate to maintain the invertebrate assemblage in its PES. **Riparian vegetation:** This site was heavily disturbed, especially the upper zone which resulted in few reliable indicators and mixed responses to artificial pools where excavations had taken place. Riparian indicators in the marginal and lower zones were fair but resource utilisation (such as grazing) was high. Recent hydraulic lookup tables were available but confidence in large infrequent floods is lower due to the absence of cues. Confidence that high flows will maintain the PES is moderate and assumes that zero flows and non-flow related impacts remain unchanged. **Geomorphology:** Confidence in the flood requirements at this site is moderate because, although the PBMT modelling results correlated with some morphological cues, the site is highly disturbed from sand mining. Additionally, the flow gauge records from the downstream weir also incorporate the flows of a large tributary. Flood requirements have been reduced to account for this, as well as for the low (D EC) Ecological condition of the geomorphology in the reach.	2.75
Mk_I_EWR1	4	4	3	4	**Fish:**These flows should be adequate to attain the specific EC for fish. The dry season flows adequate to ensure the survival of the small rheophilic fish species (*A. natalensis*) while adequate fast habitats will be available during the wet season for all life processes of the large semi-rheophilic *L. natalensis* (used as the indicator guild) to ensure the maintenance of the instream biota in the PES.	3.5

EWR site	Fish	Inverts	Riparian vegetation	Geomorphology	Comment	Overall confidence
					Inverts: Dry season flows required by the small rheophilic fish species and wet season flows driven by the requirements of a large semi-rheophilic fish species should be adequate to maintain the invertebrate assemblage in its PES.	
					Riparian vegetation: Disturbance at the site was high and there were insufficient riparian zone indicators in places. Some of these indicators occurred at distance from the transect/s which reduces certainty. Woody vegetation that had been surveyed previously could in most cases be found again, but not non-woody indicators. High confidence estimations of floods were possible using hydraulic lookup tables and there were hydrological data to verify whether estimated requirements were realistic in terms of available present day flows. The estimated requirement covers a range of floods and also considers channel morphology associated with vegetation distribution within the riparian zone. Confidence that the flooding regime will maintain the PES of the riparian vegetation is moderate and assumes that base flows are sufficient and that non-flow related impacts remain unchanged.	
					Geomorphology: Confidence in the flood requirements at this site are fairly high because of the long flow record and outputs of PBMT modelling which correlated very well with the vegetation cues at the site.	
Mk_I_EWR2	4	4	4	3.5	**Fish:**These flows should be adequate to attain the specific EC for fish. The dry season flows adequate to ensure the survival of the small rheophilic fish species (*A. natalensis*) while adequate fast habitats will be available during the wet season for all life processes of the large semi-rheophilic *L. natalensis* (used as the indicator guild) to ensure the maintenance of the instream biota in the PES.	3.75
					Inverts: Dry season flows required by the small rheophilic fish species and wet season flows driven by the requirements of a large semi-rheophilic fish species should be adequate to maintain the invertebrate assemblage in its PES.	
					Riparian vegetation: Disturbance at the site was high in the upper zone but there were sufficient riparian zone indicators on both banks and in the marginal and lower zones. Woody vegetation that had been surveyed previously could not be verified in the field. High confidence estimations of floods were possible using hydraulic lookup tables and there were hydrological data to verify whether estimated requirements were realistic in terms of available present day flows. The estimated requirement covers a range of floods and also considers channel morphology associated with vegetation distribution within the riparian zone. Confidence that the flooding regime will maintain the ecological category of the riparian vegetation is high but assumes that base flows are sufficient and that non-flow related impacts remain unchanged.	
					Geomorphology: Confidence in the flood requirements at this site is high because the morphological cues at the site correlated very well with similar flood requirements to those at the upstream Mk EWR 1. Floods at Mk EWR 1 have high confidences.	
Mk_I-EWR3	4	4			**Fish:**These flows should be adequate to attain the specific EC for fish. No rheophilic species is present and hence the rheophilic invertebrate used as dry season indicator will ensure adequate flows for fish. Adequate fast habitats will be available during the wet season for the large semi-rheophilic *L.s natalensis* (used as the indicator guild) to ensure the maintenance of the instream biota in the PES.	2.25
					Inverts: Adequate fast habitats should be available during wet season (as determined for semi-rheophilic fish) and dry season to maintain the indicator taxon and the invertebrate assemblage as a whole in the PES.	
					Riparian vegetation: When the site was visited in 2013 the benchmarks were not found so riparian vegetation indicators were surveyed relative to the water level on the day. The discharge associated with the water level was used to calculate the elevation of the water level using 1998 rating curves and this elevation used to correct all vegetation levels to ascertain elevation above the channel bed for all vegetation survey points. Although a full suite of riparian indicators were present at the site, this resulted in a lower confidence in the accuracy of estimation for high flows, together with the assumption that the channel morphology had not changed since 1998 (since the profile and lookup tables used for new survey points were from 1998). Also, many marginal and lower zone samples were available but less upper zone samples means that confidence is lower for bigger floods. Confidence that the requested flooding regime will maintain the PES is thus low.	
					Geomorphology: Confidence in the flood requirements at this site is moderate because PBMT was not undertaken for this site. Although the morphological cues at the site are weak, they are well correlated with similar flood requirements to those at the upstream Mk EWR 1 and 2 sites. Floods at Mk EWR 1 have high confidences.	

17.2.4 Confidence in Hydrology

Note: If natural hydrology was used to guide requirements, then that confidence will carry a higher weight than normal. Hydrology confidence is provided from the perspective of its usefulness to the EWR assessment. This will be different than the confidence in the hydrology for water resources management and planning. The scale of requirements is very different, and therefore high confidence hydrology for water resource management purposes often does not provide sufficient confidence for EWR assessment. The hydrology confidence is summarised in Table 17.6.

Table 17.6 Confidence in hydrology

EWR site	Natural hydrology	Present hydrology	Comment	Confidence: Median	Confidence: Average
Mv_I_EWR1	2	2	The lack of a gauge results in a lower confidence.	2	2
Mv_I_EWR2	2	1	The lack of a gauge results in a lower confidence.	1.5	1.5
Mg_I_EWR2	3	3	There is no reliable gauge near the site. However U2H048 is the closest gauge situated just below Midmar Dam and upstream of EWR site (1968 – 2014).	3	3
Mg_I_EWR5	3	3	U2H055 (upstream of site) with 24 years (1989 – 2013) of data; and U2H002 (downstream of site) but includes runoff from Mqeku tributary with 47 years of data (1928 – 1975).	3	3
Mk_I_EWR1	3	3	U2H005 (upstream of EWR site) with 54 years (1960 to 2014) of data.	3	3
Mk_I_EWR2	3	3	U1H002 is the closest gauge (upstream of site) but with no usable record as observations were only made for about 2 years (1933 to 1935).	3	3
Mk_I_EWR3	3	3	U1H009 which has a good, but short record (2004 – 2014).	3	3

17.2.5 Overall confidence in EWR results

The overall confidence in the results are linked to the confidence in the hydrology and hydraulics as the hydrology provides the check and balance of the results and the hydraulics convert the requirements in terms of hydraulic parameters to flow. Therefore, the following rationale was applied when determining the overall confidence:

- If the hydraulics confidence was lower than the biological responses column, the hydraulics confidence determined the overall confidence. Hydrology confidence was also considered, especially if used to guide the requirements.
- If the biological confidence was lower than the hydraulics confidence, the biological confidence determined the overall confidence. Hydrology confidence was also considered. If hydrology was used to guide requirements, than that confidence would be overriding in determining the overall confidence.

The overall confidence in the EWR results is provided in Table 17.7.

Table 17.7 Overall confidence in EWR results

Site	Hydrology	Biological responses Low flows	Hydraulic: Low Flows	OVERALL: LOW FLOWS	Comment	Biophysical responses: High flows	Hydraulics: High Flows	OVERALL: HIGH FLOWS	Comment
Mv_I_EWR1	2	3	3	**3**	Wet season within measured flow range, dry season below measured flow range; short riffle - non-uniform conditions; large roughness elements	2.5	3	**3**	High flows above measured flow range
Mv_I_EWR2	1.5	4	2	**2**	Wet and dry seasons below measured flow range	2.75	3	**2.75**	High flows above measured flow range
Mg_I_EWR2	3	3	2	**2**	Wet and dry seasons below measured flow range	3.5	4	**3.5**	Within-year high flows largely within observed flow range
Mg_I_EWR5	3	5	4	**4**	Wet season within measured flow range, dry season below measured flow range	3	5	**3**	High flows within measured flow range
Mk_I_EWR1	3	4	3	**3**	Wet season within measured flow range, dry season below measured flow range; short rapid with bedrock - non-uniform conditions; large roughness elements	3.5	4	**3.5**	Within-year high flows largely within observed flow range; non-uniform flow conditions
Mk_I_EWR2	3	4	3	**3**	Wet season within measured flow range, dry season below measured flow range; large roughness elements	3.75	5	**3.75**	Within-year high flows largely within observed flow range
Mk_I_EWR3	3	4	4	**4**	Wet season within measured flow range, dry season largely within measured flow range	2.25	5	**2.25**	Within-year high flows largely within observed flow range

17.3 RECOMMENDATIONS

The confidence for all the parameters (Table 17.8) is generally Moderate and High. The only low confidence is with Mvoti hydrology and this is linked to the available hydrological model for the Mvoti River which is out of date.

Confidence in the hydraulic modelling results overrides the confidence in the biophysical responses and EWR determination. Although the confidence is generally Moderate and High for the lower uMngeni and Mkomazi Rivers, it is Moderate for the Mvoti and Mg_I_EWR. The lowest confidence evaluation is at the Mv_I_EWR 2 site and this is because all measured flow data used for calibrating the hydraulic model was higher than the low flow EWR determination. Further work to improve the hydraulics would require additional measured calibration at very low flows.

The most effective way of improving confidence is linked to monitoring the ecological status of the river and, if required, improving the hydraulics for low flows at selected sites as part of the monitoring programme. No specific studies to improve any confidences other than the monitoring are therefore recommended.

Table 17.8 Confidence summary

EWR site	Mv_I_ EWR1	Mv_I_ EWR2	Mg_I_ EWR2	Mg_I_ EWR5	Mk_I_ EWR1	Mk_I_ EWR2	Mk_I_ EWR3
Data availability	3	2.8	3	3	3	3	3
Eco-Classification	3.3	3.1	3	3.1	3	3	3
Low flow EWR (biotic responses)	3	4	3.3	5	4.3	4.3	4
High flow EWR (biophysical responses	2.5	2.75	3.5	2.75	3.5	3.75	2.25
Hydrology	2	1.5	3	3	3	3	3
Hydraulics (low)	3	2	2	4	3	3	4
Hydraulics (high)	3	3	4	5	4	5	5
Overall low flow EWR confidence	3	2	2	4	3	3	4
Overall high flow EWR confidence	3	2.75	3.5	3	3.5	3.75	2.25

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19 APPENDIX A: WATER QUALITY PRESENT STATE ASSESSMENT: INTERMEDIATE EWR SITES

19.1 INTRODUCTION

The study area includes selected water resources in the Mvoti to Umzimkulu WMA, i.e. WMA11. The report below covers the following steps per INTERMEDIATE 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.

19.1.1 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, i.e. Appendix B.

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 – utilized in assessment where relevant.
- Information from project reports (DWA, 2013a,b).

19.1.2 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.

19.2 DELINEATION AND EWR 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 19.1.

Table 19.1 Additional water quality information per EWR site

EWR site name	River	RHP[1] site	Quat	WQ monitoring gauge (WMS code)	Umgeni Water site
Mv_I_EWR1	Heine-spruit	None	U40B	U4H002Q01 on Mvoti River (WMS102677)	RMV005 on Heinespruit at Mispah.
Mv_I_EWR2	Mvoti	U4MVOT_DSHLI	U40H	U2H007Q01 in U4J (WMS102678)	RHB001on Hlimb River upstream of Mvoti confluence.
Mg_I_EWR2	uMngeni	U2MGEN_MORTO	U20E	U2H0055Q01 at Howick U2H048Q01 (WMS102621), downstream weir at Midmar Dam (WMS102658).	RMG008 on uMngeni at Mortons Drift. RMG036 downstream of Merrivale stream.
Mg_I_EWR5	uMngeni	U2MGEN_USUMC	U20L	U2H001Q01 at Inanda. Location Egugwini (WMS87822). U2H015Q01 downstream (WMS102630).	RMG020 Inanda inflow downstream. RMG017 at Inanda weir.
Mk_I_EWR1	Mkomazi	U1MKOM-LUNDY	U10E	U1H005Q01 (WMS102619).	RMK002, Mkomazi at weir U1H005 Lundys.
Mk_I_EWR2	Mkomazi	None	U10J	U1H001Q01 downstream (WMS102618).	RMK004, Mkomazi downstream at Josephine Bridge.
Mk_I_EWR3	Mkomazi	U1MKO-USCRA	U10M	U1H009Q01 at Shozi (WMS190361). U1H006Q01 at Shozi, Delos Estate (WMS102620)	No data.

19.3 RESULTS

19.3.1 Mv_I_EWR1: Heinespruit, tributary of the Mvoti River

The tertiary catchment, U40 (Mvoti River Catchment) is located in the Mvoti region and is comprised of the quaternary catchments U40A - J. Land use in the Mvoti Catchment consists mainly of dryland and irrigated sugar cane plantations along the coast and timber plantations (forestry) in the upper reaches, including banana plantations. Communal lands occur inland around Mapamulo and extensive invasive alien vegetation has transformed the catchment. The DWA Water Quality Review Report (2009) indicates good water quality in the upper reaches of the Mvoti River at Mistley (U40B2), whereas a declineoccurs further downstream of the Nsuze River at Glendal in the middle reaches (U40H3) with an increase in conductivity and nutrient concentrations. This is due to runoff and return flows from agriculture, urban areas and industrial discharges. To date, large-scale irrigation and resultant return flows have not caused an obvious deterioration in water quality. In conclusion, overall water quality for the catchment was assessed as Good relative to the ''fitness for water use'' quality requirements.

The 2012 Green Drop report for Wastewater Treatment Works (WWTW) in the study area that potentially impact on rivers (cited in DWA, 2013a), showed the following wastewater risk rating for the Heinespruit:

- Greytown WWTW on Heinespruit, uMzinyathi District Municipality: Medium Risk.

The water quality Status Quo report (DWA, 2013a) for the study identified the following water quality hotspot on the Heinespruit.

SQ reach	River name	Water quality impact (rating)	Water quality issues
U40B-03770	Heinespruit	Serious (4)	Pesticides and nutrients; WWTW.

The gauging weir, U4H002Q001, is on the Mvoti River upstream of the Heinespruit confluence, although it is in the same Level II EcoRegion as the EWR site (16.03) – see Figure 19.1. Note that the data record for the gauging weir is from 1977 - 2013, while Umgeni Water (UW) data for the Heinespruit (RMV005) are available from 2008-2013. The UW data is considered more representative of water quality as it is at the same position as the EWR site. Reference Condition was represented by the A category 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 Poor with a SPI score of 9.7 (i.e. a D Ecological Category). The diatom data indicated elevated salinity and nutrient levels, diminished oxygen saturation levels and high organic pollution loads/nutrient levels characteristic of sewage effluent. Deformities also indicated the presence of metal toxicity (Appendix B).

Table 19.2 shows the water quality present state assessment for the site, and the PAI table is provided electronically.

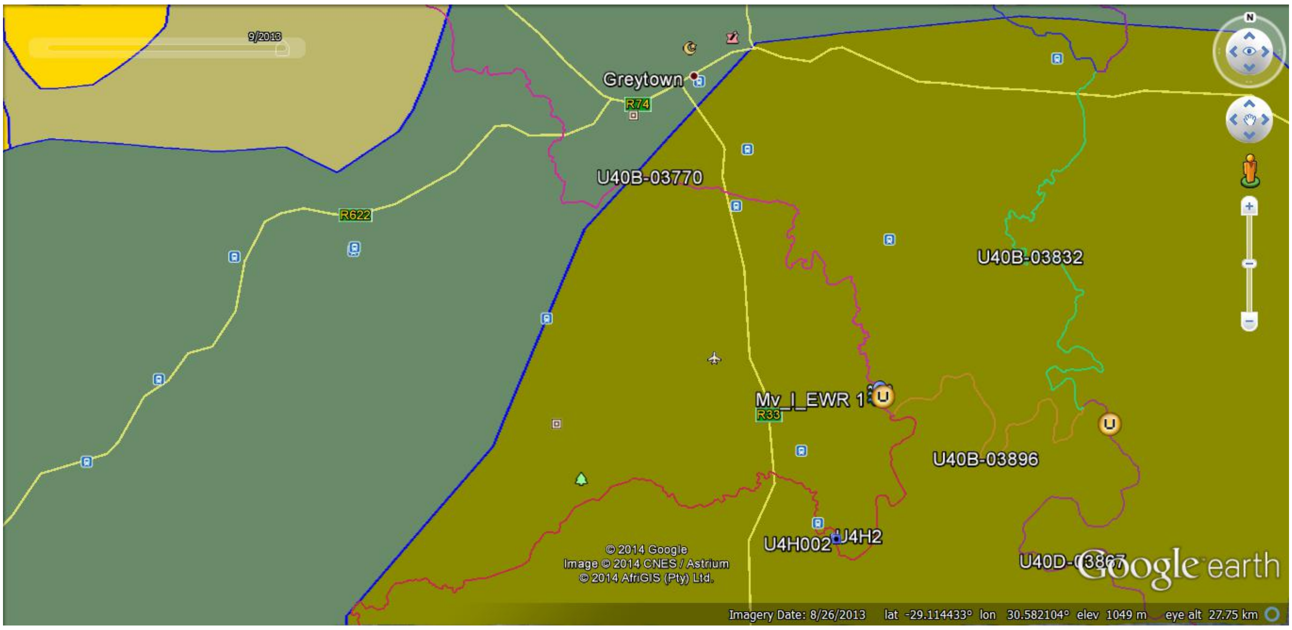

Figure 19.1 Google Earth image showing EWR site Mv_I_EWR1, Umgeni site RMV005 and gauging weir U4H002Q01

Table 19.2 Water quality present state assessment for Mv_I_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)	27.7	A
Nutrients (mg/l)		
SRP	0.154	E
TIN	2.28	D
Physical Variables		
pH (5^{th} + 95^{th} %ile)	7.1and8.0	A
Temperature (ºC)	Median: 18	A. Natural temperature range expected.
Dissolved oxygen (mg/L)	-	A/B. Some man-made modifications in the catchment but no known problems or concerns about DO.
Turbidity (NTU)	Median: 12.9 Mean: 18.6 Max: 85.7	B. Changes in turbidity appear to be related to minor man-made modifications. Some silting of habitats expected.
Response variables		
Chl-*a*: phytoplankton (ug/L)	-	
Macro-invertebrate score (MIRAI) SASS score ASPT score	72.2%	C
Diatoms	SPI = 9.7 (n = 1)	D
Fish score (FRAI)	65%	C
Toxics		
Ammonia (as N)	0.932	> E
Fe	Min: 0.01 Max: 3.9	TWQR not met as fluctuation is more than 10% (DWAF, 1996a).
Mn	0.11	A
Microbial indicator (counts/100 ml): *E. coli*	Median: 480 Mean: 2 385 Max: 35 000	The mean value exceeds the TWQR of 0 - 130 counts/100mL (DWAF, 1996b) for full-contact recreational use.
OVERALL SITE CLASSIFICATION (PAI model)		**C (71%)**

-no data

The PES for water quality as indicated by the PAI table is a **C 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. The nutrient state of the Heinespruit is very poor, with conditions being substantially worse than the main stem of the river.

19.3.2 Mv_I_EWR2: Mvoti River

The water quality Status Quo report for the study (DWA, 2013a) identified the following water quality hotspot on the Mvoti River; note the hotspot attached specifically to the SQ where the EWR site is located, i.e. U40H-04064.

SQ reach	River name	Water quality impact (rating)	Water quality issues
U40H-04064	Mvoti	Large (3)	Discharge from agriculture, urban and industrial areas .
U40J-03998	Mvoti	Large (3), especially around KwaDukuzu	Sugar (Illovo) and paper mill effluents; WWTW so elevated nutrients; high turbidity levels; urban impacts (Stanger).

The gauging weir, U4H007Q001 in EcoRegion 17.01, is downstream of the EWR site, which is located in EcoRegion 17.03. The closest Umgeni Water sampling site, RHB001001, is on the Hlimbitwa River upstream of the Mvoti confluence (Figure 19.2). Note that the data record for the gauging weir is from 1977-1997, while Umgeni Water data are available from 2008-2013. The latter data were therefore used to represent present state. Reference Condition was represented by the A category tables in DWAF (2008). This was considered suitably representative of the natural state in the area. Note that there is low confidence in this water quality assessment as neither the DWA data or UW data are truly representative of the conditions at the site.

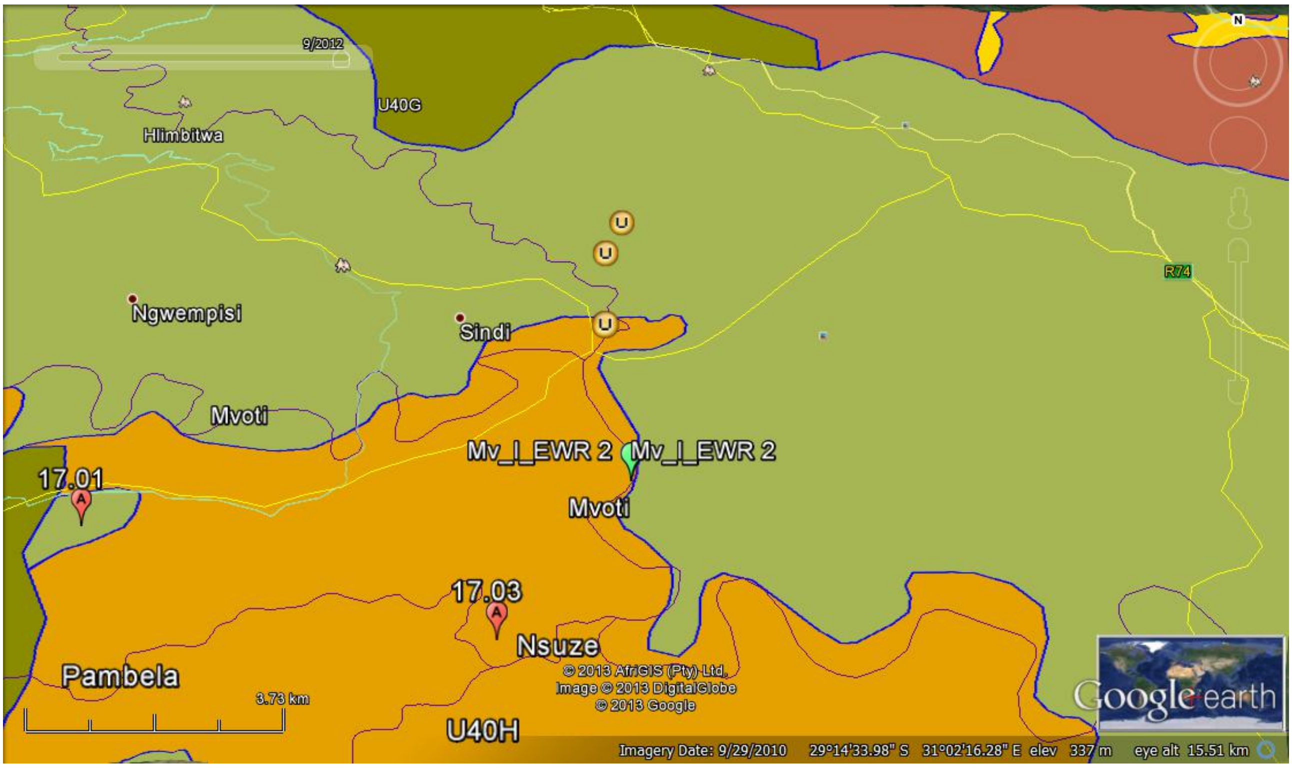

Figure 19.2 Google Earth image showing EWR site Mv_I_EWR2 and Umgeni sites on the Hlimbitwa and tributaries

The diatom analysis (n=2, June and August 2013) indicated that the biological water quality at this site was Good during June and August respectively, with the SPI score being between 17.1 and 16.7 (A/B - B Ecological Category). Nutrient and salinity levels were elevated but not problematic during sampling periods and remained relatively stable. However, the following issues noted at the site resulted in the final PES for diatoms set at a B/C with an average score of 14.5 (Appendix B):

- The outright presence of *A. crassum*;
- the presence of indicator species for anthropogenic impacts; and
- the presence of valve deformities.

Table 19.3 shows the water quality present state assessment for the site, and the PAI table is provided electronically.

Table 19.3 Water quality present state assessment for Mv_I_EWR2

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)	15.3	A
Nutrients (mg/l)		
SRP	6.0	> E
TIN	0.277	A/B
Physical Variables		
pH (5^{th} + 95^{th} %ile)	8.0 *	A/B
Temperature (ºC)	-	A. Natural temperature range expected.
Dissolved oxygen (mg/L)	-	A/B. Some man-made modifications in the catchment but no known problems or concerns about DO.
Turbidity (NTU)	Median: 9 Mean: 61 Max: 1363	B. Some fluctuations in turbidity expected due to sedimentation, overgrazing, trampling and vegetation removal in the riparian zone.
Response variables		
Chl-*a*: phytoplankton (ug/L)	-	
Macro-invertebrate score (MIRAI) SASS score ASPT score	79.8%	B/C
Diatoms	SPI=14.5(n=2)	B/C
Fish score (FRAI)	78.0%	B/C
Toxics		
Ammonia (as N)	0.206	E/F
Al	2.343	> E
Microbial indicator (counts/100 ml): *E. coli*	Median: 790 Mean: 1 678 Max: 11 200	The mean value exceeds the TWQR of 0 - 130 counts/100mL (DWAF, 1996a) for full-contact recreational use.
OVERALL SITE CLASSIFICATION (PAI model)		**C (76.2%)**

- no data.
* Taken by Kotze in Aug 2013 (n = 1).

The PES for water quality is a **C category**, with a LOW confidence as no reference condition data were available for use and the data used for the assessment is on an upstream river in the adjacent EcoRegion.

19.3.3 Mg_I_EWR2: 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 main land-use in the upper areas were agriculture and forestry, with urban areas downstream Midmar Dam, e.g. Howick and Hilton. Note that these urban areas include both formal and informal type settlements, with associated deteriorations in water quality due to return flows and runoff from agriculture and urban / peri-urban areas.

The 2012 Green Drop report for Wastewater Treatment Works (WWTW) in the study area that potentially impact on rivers (cited in DWA, 2013a), showed the following wastewater risk ratings:

- Howick WWTW on the uMngeni River, eThekwini MM: **Low Risk.**

However, the following situation is evident around the town of Howick. The photograph below appeared in The Witness of 19 September 2013, depicting a child walking across a “sewage” river at an informal settlement between Howick West and Siphumelele. Italicized text below is taken directly from The Witness.

*The “river” flows from Howick South, under the N3 highway, under the reef-coast railway line, through the informal settlements of Muthandabisi and Thokoza, and is fed by Howick West and Siphumelele. The situation is compounded by the inadequate Bridge Sewage Pump Station that often spills raw sewage straight into the uMngeni River.*Apparently this faulty pump spills just about every day and has been doing so for a long time.Other problems in the area include sewage spilling into the Merrivale stream and into the uMngeni River below Howick Falls.

The water quality Status Quo report for the study (DWA, 2013a) identified the following water quality hotspots in the area. Note the hotspot attached specifically to the SQ where the EWR site is located, i.e. U20E-04243, which is downstream Howick town.

SQ reach	River name	Water quality impact (rating)	Water quality issues
U20E-04243	uMngeni	Large (3)	Elevated nutrient loads; urban run-off.
U20F-04224	Mpolweni	Large (3)	High nutrient load.
U20G-04194	Mkabela	Large (3)	High nutrient load; toxics may be present.
U20G-04215	Cramond Stream	Large (3)	High nutrient load; toxics may be present.
U20G-04240	uMngeni	Large (3)	High nutrient load.
U20G-04385	uMngeni	Large (3)	High nutrient load; urban impacts.

Water quality monitoring points in the area are the following: (1) The gauging weir, U2H001Q001, on the uMngeni River upstream of the EWR site at Howick, (2) the gauging weir, U2H048Q001 on the downstream weir at Midmar Dam which is upstream Howick town, (3) UW monitoring point on the uMngeni River downstream Merrivale Stream and upstream of the EWR site, and (4) UW monitoring point RMG008 on the uMngeni River @ Mortons Drift downstream of the EWR site – see Figure 19.3 for the position of the EWR site in relation to the upstream DWA monitoring point and the UW Merrivale point upstream of the EWR site.A number of other UW points are also present in the area. Note that although data from U2H001Q01 and the Merrivale UW point were assumed to be most representative of water quality state for the site, U2H001Q01could not be used as data are only available from 1977-1995 and the weir is no longer active. Note that both the DWA and Merrivale sites are just within the adjacent EcoRegion (16.01), and that there is a distance of approximately 6.5km between the UW point and the EWR site. Mortons Drift is downstream the EWR site and within the same EcoRegion. This data was also evaluated for use. Umgeni Water (UW) Merrivale data are available from 2010-2013 and Mortons Drift 2008-2013. Reference Condition was represented by the A category tables in DWAF (2008). This was considered suitably representative of the natural state in the area.

The diatom results indicated that the water quality was moderate to good during June and August 2013 (n=2) and the SPI score was 12.4 and 15.2 respectively (C and B Ecological Category). However, the final PES for diatoms was set at a C/D category with an average score of 12.2 due to the following (Appendix B):

- The outright presence of *A. crassum* during the August 2013 sample influencing the SPI score;
- the dominance of indicator species for anthropogenic impacts during August 2013; and
- the presence of valve deformities at abundances above threshold limits during June and August 2013.

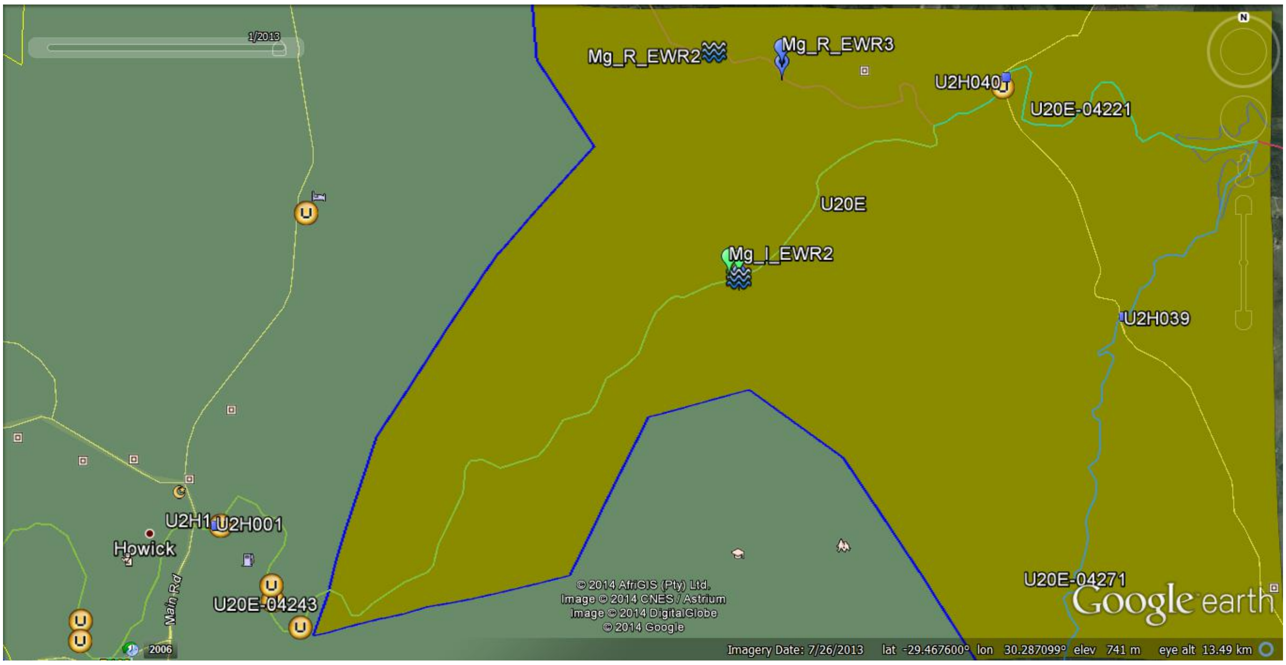

Figure 19.3 Google Earth image showing EWR site Mg_I_EWR2 downstream of Howick town, Umgeni site RMB036 and gauging weir U2H001Q01

Table 19.4 shows the water quality present state assessment for the site, and the PAI table is provided electronically. Note that results from the UW Merrivale site are shown in italics on Table 19.4.

Table 19.4 Water quality present state assessment for Mg_I_EWR2

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)	12.0 *12.3*	A *A*
Nutrients (mg/l)		
SRP	0.027 *0.050*	C/D *D*
TIN	0.54 *0.7*	B *B/C*
Physical Variables		
pH (5^{th} + 95^{th} %ile)	7.1 and 8.3 *7.3 and 8.3*	B *B*
Temperature (ºC)	*Median: 17.4*	*A. Natural temperature range expected.*
Dissolved oxygen (mg/L)	*7.1*	*B. Some man-made modifications in the catchment but no known problems or concerns about DO.*
Turbidity (NTU)	*Median: 11.7* *Mean: 17.1* *Max: 44.5*	*B. Changes in turbidity appear to be related to minor man-made modifications.*
Response variables		
Chl-*a*: phytoplankton (ug/L)	-	
Macro-invertebrate score (MIRAI) SASS score ASPT score	76.1%	C
Diatoms	SPI = 12.2 (n = 2)	C/D
Fish score (FRAI)	27%	E
Toxics		
Ammonia (as N)	0.153 *0.6*	C/D *> E*
Fe	*Min: 0.38* *Max: 2.0*	*TWQR not met as fluctuation is more than 10% (DWAF, 1996a).*
Mn	0.146	
Al	0.711	*> E*
As	*Below detection*	*A*
Cn	*Below detection*	*A*
Cd	*Below detection*	*A*
Cr *	0.004	*A*
Cu	*Below detection*	*A*
Hg	*0.000 55*	*Exceeds the TWQR and CEV for aquatic ecosystems (DWAF, 1996a)*
F	*Below detection*	*A*
Mn	*0.146*	*A. Within the TWQR for aquatic ecosystems (DWAF, 1996a)*
Ni	*0.07*	*Only livestock and irrigation guidelines. Value is within the TWQR.*
Pb **	*0.007*	*D*

Water Quality Constituents	PES Value	Category/Comment
Zn	*Below detection*	*A*
Microbial indicator (counts/100 ml): *E. coli*	Median: 170 Mean: 909 Max: 9290 *Median: 1 520* *Mean: 2 915* *Max: 10 460*	*The mean value exceeds the TWQR of 0-130 counts/100mL (DWAF, 1996b) for full-contact recreational use.*
OVERALL SITE CLASSIFICATION (PAI model)		**C (66.4%)**

- no data.
* assume Cr (III).
** assume moderate hardness.

The PES for water quality as indicated by the PAI table is a **C category**, with a MODERATE confidence as no reference condition data were available for use. There is moderate confidence in the present state data as a small data record was used for the Merrivale site. The deleterious impact of the Merrivale Stream on the uMngeni River is obvious, although conditions downstream are still poor in terms of nutrient and *E.coli* loads.

19.3.4 Mg_I_EWR5: uMngeni River

The EWR site is located between Nagle and Inanda dams. Water released from the lower layers of Nagle Dam results in higher nitrate, phosphate and turbidity levels than in the dam itself. The confluence of the uMngeni and uMnsunduze rivers is below Nagle Dam and upstream from the EWR site. The uMnsunduze River flows eastwards to Henley Dam, Edendale and Pietermaritzburg (WRC, 2002; cited in DWA, 2013a). 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 (DWAF, 2004).

Forestry and large-scale sugar cane production with related erosion potential is found in the central area of the uMngeni catchment, with limited, reasonably well-controlled pollution from cattle feedlots and poultry operations. There is some intensive vegetable production with resultant nutrient and pesticide problems. Cultivation on steep slopes is common in the moderately populated areas in the Valley of a Thousand Hills which results in moderate to high erosion and some faecal contamination. Dense urban and industrial use occurs downstream of Inanda Dam, with serious faecal and varied industrial contamination likely (DWAF, 2004b; cited in DWA, 2013a).

The water quality Status Quo report for the study (DWA, 2013a) identified the following water quality hotspots in the area. Note the hotspot attached specifically to the SQ where the EWR site is located, i.e. U20L-00435, which is downstream Nagle Dam.

SQ reach	River name	Water quality impact (rating)	Water quality issues
U20L-04435	uMngeni	Large (3)	Urban impacts; nutrient elevations.
U20M-04396	uMngeni	Serious (4)	Urban impacts; nutrient elevations; aquatic plants in upstream dam so low DO levels; treated effluent coming in from the Piesang in the north (below Inanda). Note the input of the Mhlangane River, which is a hotspot identified by eThekweni MM
U20M-04639	Palmiet	Large (3)	Elevated nutrients.
U20M-04642	Palmiet	Serious (4)	Elevated nutrients and industrial discharges.

U20M-04653	Palmiet	Large (3)	Elevated nutrients.

Water quality monitoring points in the area are the following: (1) The gauging weir, U2H055Q001, upstream from the EWR site, (2) the gauging weir, U2H015Q001 downstream from the EWR site, (3) UW monitoring point RMG017 upstream at Inanda Weir, and (4) UW monitoring point RMG020 downstream at the Inanda Dam inflow – see Figure 19.5. All monitoring points are in the same Level II EcoRegion as the EWR site. Although all data were evaluated for use, the upstream DWA and UW sites were used for the analysis. Umgeni Water (UW) data are available from 2008-2013, while data from U2H055Q01 are from 1990-2013. Reference Condition was represented by the A category tables in DWAF (2008). This was considered suitably representative of the natural state in the area.

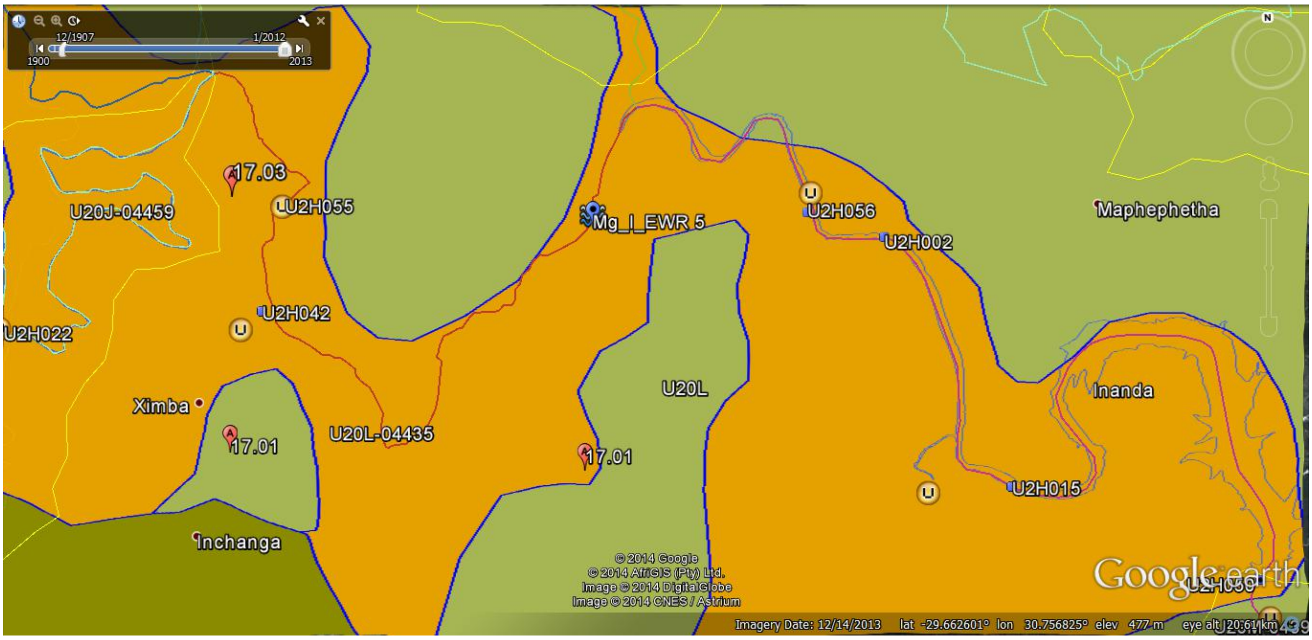

Figure 19.4 Google Earth image showing EWR site Mg_I_EWR5 and the associated DWA and UW monitoring points

Diatoms were sampled for the study (June and August 2003). Data from the 2006 State of Rivers Report were available for the following SQs:

- SQ U20G-04385: This SQ is situated upstream of EWR 5 and the site was identified as the uMngeni causeway downstream of Nagle Dam. Diatom conditions at the time was Fair (SPI score: 9 – 13), although it was noted that the score was influenced by recent flooding and spills from Nagle Dam.
- SQ U20M-04396: This SQ is situated downstream of EWR 5 and Inanda Dam and the site was identified as uMngeni upstream of the Mzinyati confluence. The diatoms showed that the biological water quality condition at the time was Natural (SPI score: >17), although it was noted that the score was influenced by recent flooding.
- SQ U20M-04543: This SQ is situated in the lower reaches of the uMngeni River in the area of Reservior Hills downstream of EWR 5 and Inanda Dam. The site was identified as uMngeni upstream of Silver Pipe. Diatoms showed the biological water quality condition at the time as Good (SPI score: 13 - 17).

Based on available information the diatom-based water quality was determined to be in a C/D Ecological Category for the EWR reach, where the water is characterised by elevated nutrient and salinity levels due to anthropogenic activities which include urban impacts (Koekemoer, 2013).

Table 19.5 shows the water quality present state assessment for the site, and the PAI table is provided electronically. The UW results are shown in *italics.*

Table 19.5 Water quality present state assessment for Mg_I_EWR2

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)	41.9 *38.3*	B *B*
Nutrients (mg/l)		
SRP	0.052 *0.061*	D *D*
TIN	3.45 *2.69*	D/E *D*
Physical Variables		
pH (5^{th} + 95^{th} %ile)	7.4 and 8.7 *7.2 and 8.3*	B *B*
Temperature (ºC)	*Median: 17.4*	*A. Natural temperature range expected.*
Dissolved oxygen (mg/L)	-	B. Some man-made modifications in the catchment but no known problems or concerns about DO.
Turbidity (NTU)	*Median: 17* *Mean: 24.5* *Max: 95*	*B. Changes in turbidity appear to be related to minor man-made modifications.*
Response variables		
Chl-*a*: phytoplankton (ug/L)	-	
Macro-invertebrate score (MIRAI) SASS score ASPT score	61.9%	C/D
Diatoms	SPI=12.0	C/D
Fish score (FRAI)	54.8%	D
Toxics		
Ammonia (as N)	*0.161*	*> E*
F	*0.37* *0.153*	*A* *A*
Microbial indicator (counts/100 ml): *E. coli*	*Median: 130* *Mean: 287* *Max: 4 880*	*The mean value exceeds the TWQR of 0-130 counts/100mL (DWAF, 1996b) for full-contact recreational use.*
OVERALL SITE CLASSIFICATION (PAI model)		**C (67.2%)**

- no data.

The PES for water quality as indicated by the PAI table is a **C category**, with a MODERATE confidence as no reference condition data were available for use. There is moderate confidence in the present state data.

19.3.5 Mk_I_EWR1: Mkomazi River

The catchment is broadly characterised by having the headwaters in an area which is under conservation and then passes through alternating bands of subsistence farming and commercial agriculture (including commercial plantations). Overgrazing and high population densities in the upper, middle and lower parts of the catchment have resulted in increased sediment yields, with extensive commercial forestry populations in the headwaters (IWR Environmental, 1998; cited in DWA, 2013b).Main urban centres include Bulwer, Mpendle, Ixopo, Richmond, Donnybrook and Umkomaas on the coast. There is therefore little urban development in most of the Mkomazi catchment, with most of the residential and industrial development associated with the towns of Umkomaas on the coast and Ixopo and Richmond inland.

Primary impacts in the area are elevated sediment loads due to activities such as overgrazing and high population numbers, resulting in elevated instream turbidity (Umgeni Water, 1998; cited in DWA, 2013b). However, no major water quality issues or hotspots were identified and the water quality of the Mkomazi is considered Good (DWAF, 1999c; cited in DWA, 2013b). The major water quality concern for the Mkomazi catchment is microbiological water quality (DWAF, 2008; cited in DWA, 2013b).

The 2012 Green Drop report for WWTW in the study area that potentially impact on rivers (cited in DWA, 2013a), showed the following wastewater risk ratings:

- Bulwer WWTW nearest the Luhane River, Sisonke DM: **High Risk**, with non-compliance with effluent quality discharge standards. Note that the WWTW is a distance away from the rivers being evaluated.

The gauging weir, U1H005Q001, and UW monitoring point RMK002 are at the EWR site and were therefore both evaluated for water quality data to represent present state (Figure 19.5). Note that the data record for the gauging weir is from 1977-2013, while Umgeni Water (UW) data are available from 2008-2013. Reference Condition was represented by the A category tables in DWAF (2008). This was considered suitably representative of the natural state in the area.

The diatom-based water quality was high with a SPI score of 17.7 (A/B Ecological Category; n=1, June 2013). Nutrient, salinity and organic pollution levels were low and the diatom community was characterised by species preferring good water quality with a low tolerance for pollution (Appendix B).

Table 19.6 shows the water quality present state assessment for the site, and the PAI table is provided electronically. UW results on Table 19.6 are shown in *italics*.

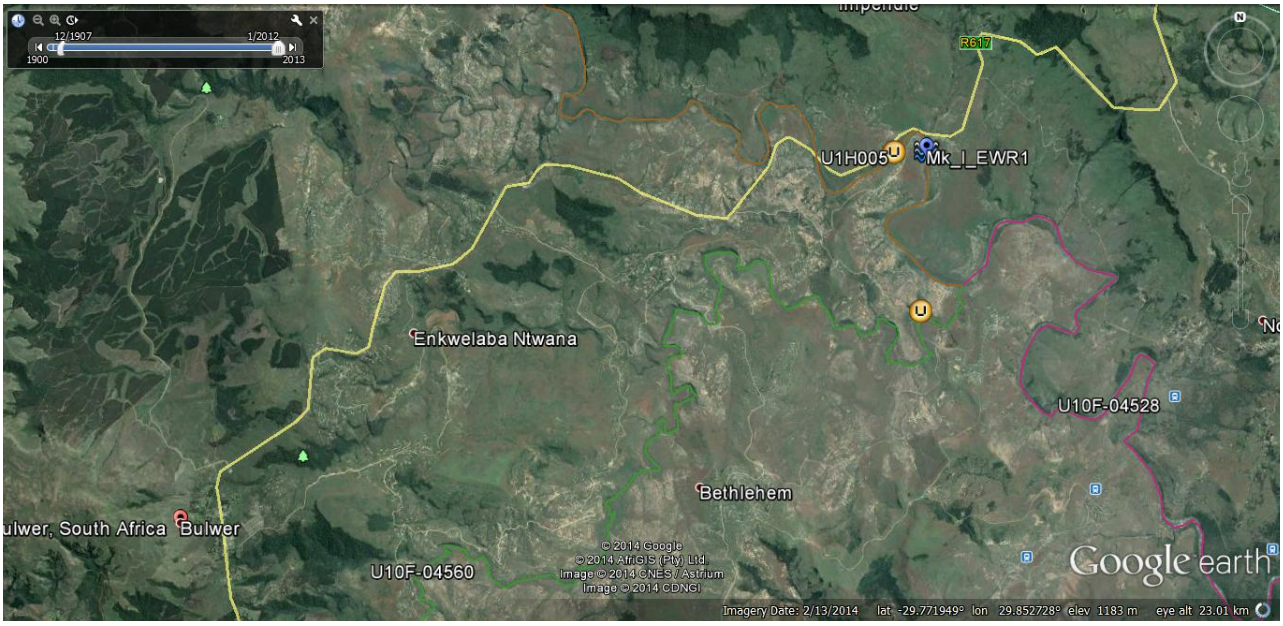

Figure 19.5 Google Earth image showing EWR site Mk_I_EWR1 and associated water quality monitoring points

Table 19.6 Water quality present state assessment for Mk_I_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)	10.9 *9.54*	A *A*
Nutrients (mg/l)		
SRP	0.013 *0.003*	B/C *A*
TIN	0.12 *0.07*	A *A*
Physical Variables		
pH (5th + 95th %ile)	6.3 + 8.0 *6.95 + 8.55*	A *B*
Temperature (ºC)	*Median: 18.2*	*A. Natural temperature range expected.*
Dissolved oxygen (mg/L)	-	A/B. Some man-made modifications in the catchment but no known problems or concerns about DO.
Turbidity (NTU)	*Median: 11* *Mean: 40.7* *Max: 533*	*A/B. Changes in turbidity appear to be related to minor man-made modifications. Some silting of habitats expected.*
Response variables		
Chl-*a*: phytoplankton (ug/L)	-	
Macro-invertebrate score (MIRAI) SASS score ASPT score	80.15%	B
Diatoms	SPI = 17.7 (n = 1)	A/B
Fish score (FRAI)	74.8%	C
Toxics		

Water Quality Constituents	PES Value	Category/Comment
Ammonia (as N)	*0.02*	*A*
Fe	*Min: 0.01* *Max: 1.71*	*TWQR not met as fluctuation is more than 10% (DWAF, 1996a).*
Hg	0.000 7	Exceeds the TWQR and CEV for aquatic ecosystems (DWAF, 1996a).
Microbial indicator (counts/100 ml): *E. coli*	Median: 480 Mean: 2 385 Max: 35 000	The mean value exceeds the TWQR of 0 - 130 counts/100mL (DWAF, 1996b) for full-contact recreational use.
OVERALL SITE CLASSIFICATION (PAI model)		**A/B (89.8%)**

- no data.
Below detection limits: As, CN, Cd, Co, Cu, F, Mn, Zn, V, Ni and Pb.

The PES for water quality as indicated by the PAI table is an **A/B category**, with a MODERATE confidence as no reference condition data were available for use. There is moderate confidence in the present state data.

19.3.6 Mk_I_EWR2: Mkomazi River

The gauging weir, U1H001Q001, and UW monitoring point RMK004 (Mkmozi at Josephine Bridge) are the closest water quality monitoring points, although both downstream of the EWR site (Figure 19.6). Note that the data record for the gauging weir is only from 1985 - 1988, while Umgeni Water (UW) data are available from 2009 -2013. The UW data were therefore used for the assessment. Reference Condition was represented by the A category tables in DWAF (2008). This was considered suitably representative of the natural state in the area.

The diatom analysis (n=2, June and August 2013) undertaken was for SQ reach U10J-04679. Results were an SPI score of 17.7 and 17.3 respectively. Nutrient and salinity levels were elevated but not problematic. Organic pollution levels were generally low. Due to the presence of some valve deformities and the dominance of *A. crassum*, the PES for this site was set at a B Ecological Category (Appendix B).

Table 19.7 shows the water quality present state assessment for the site, and the PAI table is provided electronically.

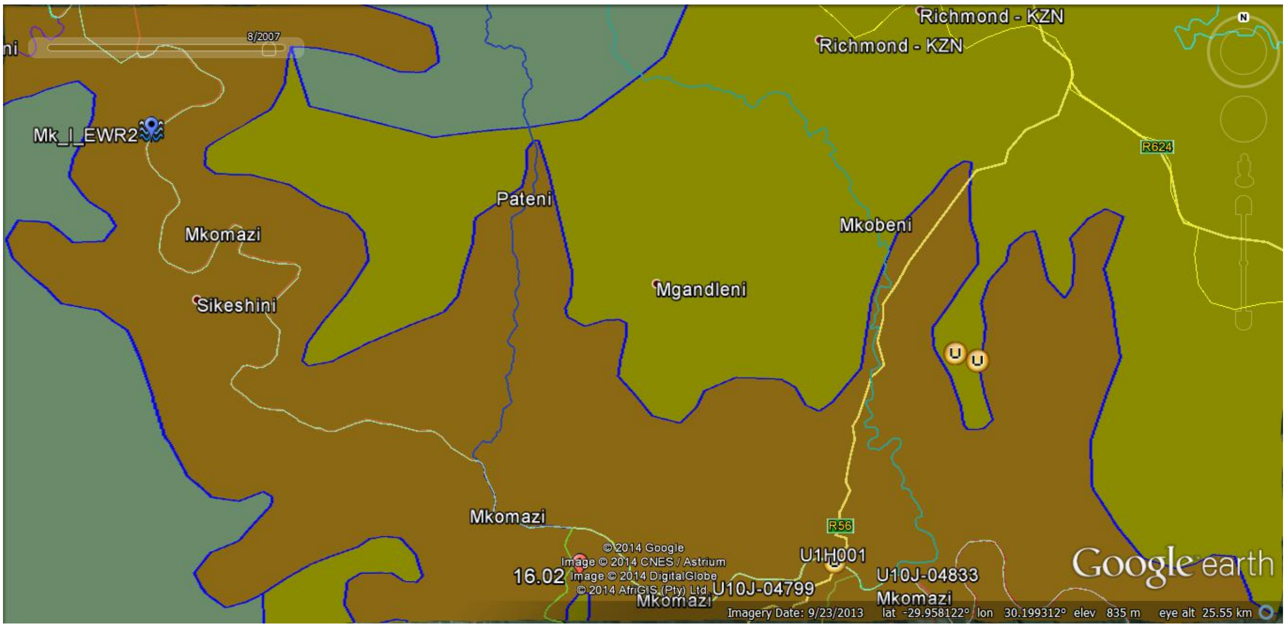

Figure 19.6 Google Earth image showing EWR site Mk_I_EWR2 and associated water quality monitoring points

Table 19.7 Water quality present state assessment for Mk_I_EWR2

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)	14.6	A
Nutrients (mg/l)		
SRP	0.006	A/B
TIN	0.145	A
Physical Variables		
pH (5^{th} + 95^{th} %ile)	7.1and 8.0	A
Temperature (ºC)	Median: 20	A. Natural temperature range expected.
Dissolved oxygen (mg/L)	-	A/B. Some man-made modifications in the catchment but no known problems or concerns about DO.
Turbidity (NTU)	Median: 27 Mean: 73 Max: 236	B. Changes in turbidity appear to be related to minor man-made modifications. Some silting of habitats expected.
Response variables		
Chl-*a*: phytoplankton (ug/L)	-	
Macro-invertebrate score (MIRAI) SASS score ASPT score	86.5%	B
Diatoms	SPI=17.7 and 17.3 (n=2)	B
Fish score (FRAI)	76.4%	C
Toxics		
Ammonia (as N)	0.068	B

Water Quality Constituents	PES Value	Category/Comment
Fe	Min: 0.16 Max: 2.33	TWQR not met as fluctuation is more than 10% (DWAF, 1996a).
Cr	0.0052	A
Mn	0.159	A
Pb *	0.004	B
Microbial indicator (counts/100 ml): *E. coli*	Median: 180 Mean: 739 Max: 5 480	The mean value exceeds the TWQR of 0 - 130 counts/100mL (DWAF, 1996b) for full-contact recreational use.
OVERALL SITE CLASSIFICATION (PAI model)		**A/B (91.0%)**

- no data.
* assume moderate or hard water
Below detection limits: As, CN, Cd, Co, Cu, F, Hg, Zn, V, Ni and Se.

The PES for water quality as indicated by the PAI table is an **A/B category**, with a MODERATE confidence as no reference condition data were available for use. There was poor confidence in the present state data as little data are available and the data is from downstream of the EWR site, even though within the same Level II EcoRegion.

19.3.7 Mk_I_EWR3: Mkomazi River

The gauging weirs, U1H009Q001 and U1H006Q01, are both downstream of the EWR site but evaluated for data as in the same Level II EcoRegion (Figure 19.7). No UW monitoring points are found in this stretch of river. Note that the data record for the gauging weir U1H009 is only from 2009 - 2013, while that of U1H006 is from 1978 - 2013. Data from both points were evaluated for the assessment. Reference Condition was represented by the A category tables in DWAF (2008). This was considered suitably representative of the natural state in the area.

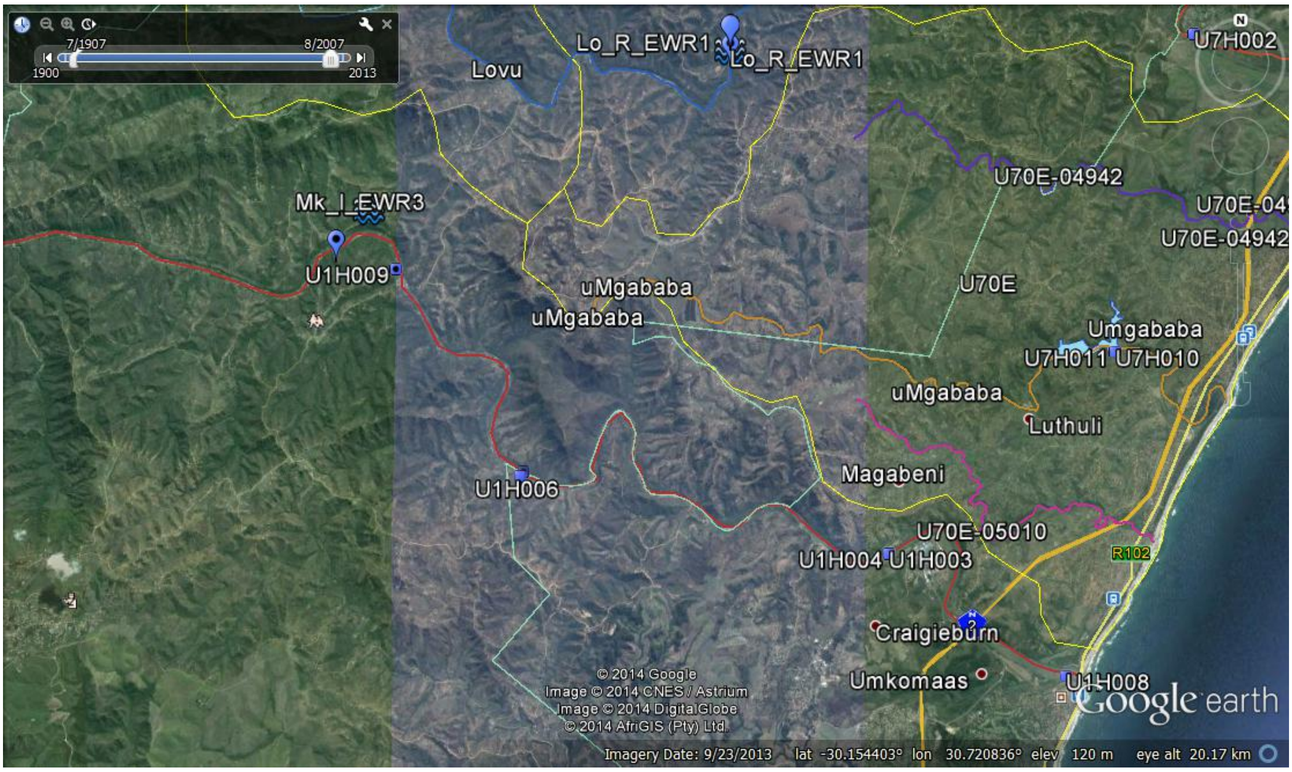

Figure 19.7 Google Earth image showing EWR site Mk_I_EWR3 and downstream gauging weirs

Diatoms were sampled for the study in June 2013 (n=1). Data from the 2006 State of Rivers Report were available for the following areas:

- A site downstream of EWR 3 @ Shozi weir was assessed.Diatoms determined that the biological water quality condition at the time was Natural (SPI score: >17).
- A site, Mkomaas @ Goodenough Barrage, was assessed during 2006 and the diatoms determined that the biological water quality condition at the time was Natural (SPI score: >17).
- A site, Mkomaas @ SAPPI SAICCOR Barrage, showed that the biological water quality condition at the time was Natural (SPI score: >17).

The diatom based water quality in June 2013 was high with a SPI score of 18.2 (i.e. an A Ecological Category). Nutrient and salinity levels, as well as organic pollution levels were elevated but not problematic (Appendix B).

Table 19.8 shows the water quality present state assessment for the site, and the PAI table is provided electronically. Results for the assessment from U1H009Q01 are shown in *italics*.

Table 19.8 Water quality present state assessment for Mk_I_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)	34.6 *49.3*	A/B *B*
Nutrients (mg/l)		
SRP	0.015 *0.005*	B/C *A/B*
TIN	0.12 0.05	A *A*
Physical Variables		
pH (5^{th} + 95^{th} %ile)	6.3 and 8.1 *7.4 and 8.3*	B *B*
Temperature (ºC)	-	A. Natural temperature range expected.
Dissolved oxygen (mg/L)	-	A/B. Some man-made modifications in the catchment but no known problems or concerns about DO.
Turbidity (NTU)	-	B. Changes in turbidity appear to be related to minor man-made modifications. Some silting of habitats expected.
Response variables		
Chl-*a*: phytoplankton (ug/L)	-	
Macro-invertebrate score (MIRAI) SASS score ASPT score	86.9%	B
Diatoms	SPI= 18.3 (n= 1)	A
Fish score (FRAI)	83.5%	B
Toxics		
F	0.288	A
OVERALL SITE CLASSIFICATION (PAI model)		**A/B (88.8%)**

- no data.

The PES for water quality as indicated by the PAI table is an **A/B category**, with a MODERATE confidence as no reference condition data were available for use. There was moderate confidence in the present state data as data are available but from downstream of the EWR site, even though within the same Level II EcoRegion.

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20 APPENDIX B: DIATOM RESULTS

20.1 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).

20.2 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)

20.3 METHODS

20.3.1 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.

20.3.2 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 semiquantitative 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).

20.3.3 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).

20.3.4 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 theSPI 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 20.1. The new adjustments will affect diatom-derived Ecological Categories from previous studies and therefore all previous results have been adjusted accordingly.

Table 20.1 Adjusted class limit boundaries for the SPI index applied in this study

Interpretation of index scores		
Ecological Category (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 freshwaterand brackishwater 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*.).

20.4 RESULTS

Diatom samples were collected at 7 EWR sites situated in Water Management Area 11 during June and August 2013. A summary of the diatom results are provided in Table 20.2 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 20.3.

Table 20.2 Diatom analysis results for Mvoti EWR Intermediate sites

Date	Site	No species	SPI score	Class	Category	PTV (%)	Deformities (%)
HEINESSPRUIT							
Jun 13	Mv_I_EWR1	55	9.7	Poor quality	D	26.8	1.75
MVOTI RIVER							
Jun 13	Mv_I_EWR2	26	17.1	High quality	A/B	2.5	2
Aug 13	Mv_I_EWR2	34	16.7	Good quality	B	5.3	1
UMNGENI RIVER							
Jun 13	Mg_I_EWR2	34	12.4	Moderate quality	C	12.3	3.75
Aug 13	Mg_I_EWR2	23	15.2	Good quality	B	28.5	2.25
Jun 13	Mg_I_EWR5	35	11.9	Moderate quality	C/D	10.8	1.5
Aug 13	Mg_I_EWR5	30	10.8	Moderate quality	C/D	13.5	1
MKOMAZI RIVER							
Jun 13	Mk_I_EWR1	19	17.7	High quality	A/B	0.8	0
Jun 13	Mk_I_EWR2	24	17.3	High quality	A/B	1.8	0
Aug 13	Mk_I_EWR2	17	17.7	High quality	A/B	0.5	1.25
Aug 13	Mk_I_EWR3	23	18.2	High quality	A	1	0.5

Table20.3 Generic diatom based ecological classification for Mvoti EWR Rapid sites

Date	Site	pH	Salinity	Organic nitrogen	Oxygen levels	Pollution levels	Trophic status
HEINESSPRUIT							
Jun 13	Mv_I_EWR 1	Alkaline	Fresh brackish	Elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Moderately polluted	Eutrophic
MVOTI RIVER							
Jun 13	Mv_I_EWR 2	Alkaline	Fresh brackish	Elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Moderately polluted	Eutrophic
Aug 13	Mv_I_EWR 2	Alkaline	Fresh brackish	Elevated concentrations of organically bound nitrogen	Continuously high (~100% saturation)	Moderately polluted	Eutrophic
UMNGENI RIVER							
Jun 13	Mg_I_EWR 2	Alkaline	Fresh brackish	Elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Moderately polluted	Eutrophic
Aug 13	Mg_I_EWR 2	Alkaline	Fresh brackish	Periodically elevated concentrations of organically bound nitrogen	Low (>30% saturation)	Very heavily polluted	Eutrophic
Jun 13	Mg_I_EWR 5	Alkaline	Fresh brackish	Elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Moderately polluted	Eutrophic
Aug 13	Mg_I_EWR 5	Alkaline	Fresh brackish	Elevated concentrations of organically bound nitrogen	Moderate (>50% saturation)	Moderately polluted	Eutrophic
MKOMAZI RIVER							
Jun 13	Mk_I_EWR1	Neutral	Fresh brackish	Elevated concentrations of organically bound nitrogen	Continuously high (~100% saturation)	Moderately polluted	Indifferent
Jun 13	Mk_I_EWR2	Neutral	Fresh brackish	Elevated concentrations of organically bound nitrogen	Continuously high (~100% saturation)	Moderately polluted	Eutrophic
Aug 13	Mk_I_EWR2	Neutral	Fresh brackish	Elevated concentrations of organically bound nitrogen	Continuously high (~100% saturation)	Moderately polluted	Indifferent
Aug 13	Mk_I_EWR3	Neutral	Fresh brackish	Elevated concentrations of organically bound nitrogen	Continuously high (~100% saturation)	Moderately polluted	Indifferent

20.5 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.

20.5.1 Mv_I_EWR1: Heinesspruit

This site was only sampled during June 2013 and is situated in the Heinesspruit, SQ reach U40B-03770. Data availability was poor and the diatom assessment is based on the one sample collected during June 2013. SQ reach U40B-03770 was identified as a water quality hotspot, with serious impacts relating to the presence of pesticides and high nutrient levels due to non-compliant Waste Water Treatment Works (WWTWs) in the area (DWA, 2013). Non-flow related impacts included forestry and vegetation removal due to agricultural activities. According to DWA (2013) the overall PES for this SQ reach was a C Ecological Category.

The SPI score for this site was 9.7 indicating generally poor water quality mainly due to high organic pollution levels which have led to diminished oxygen saturation levels (Table 1.3). The diatom data indicated that although salinity and nutrient levels were elevated these variables had the potential of becoming problematic. Dominant species generally had an affinity for high organic pollution loads and elevated nutrient levels characteristic of sewage effluent. Dominant species included *Eolimna minima* which is an indicator species of organic pollutionand has an affinity for heavily polluted waters (Taylor *et al*., 2007b). *Mayamaea atomus* var. *permitis*, an aerophilic species, was also dominant and is one of the most pollution tolerant resistant diatoms, usually found in alkaline, heavily polluted waters (Taylor *et al*., 2007b).Elevated nutrient and salinity levels are reflected by the dominance of *Cocconeis placentula.* 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.

Sedimentation could be problematic in this reach. *Navicula trivialis*is an epipelic species (i.e. species living in sandy substrate) and generally has a preference for deteriorated water quality. Biocriteria presented by Teply and Bahls (2006) use Sediment Increaser Taxa - –common diatom taxa whose relative abundance increases in response to impairment due to sediment. *Eolimna minima* was identified as a sediment increaser species as it is motile and capable of maintaining its position on aggrading substrates composed of fine sediment. The dominance of aerophilic species was also an indication of fluctuating water levels which would impact the life cycle and breeding patterns of macro-invertebrates and to some extent fish.

Valve deformities were within the threshold limit with an occurrence of 1.75% during June 2013. However this was an indication of the presence of metal toxicity which would have an adverse effect on the biotic functioning of the river.

Based on the available information the PES for diatom was set at a D EC for this reach.

20.5.2 Mv_I_EWR2: Mvoti

This site was sampled during June and August 2013 and is situated in the lower reaches of the Mvoti River, SQ reach U40H-04064. Data availability was poor and the diatom assessment is based on the two samples collected during June and August 2013. SQ reach U40H-04064 was identified as a water quality hotspot, with large impacts relating to the discharge from agriculture, urban and industrial areas(DWA, 2013). Non-flow related impacts included sedimentation, overgrazing, trampling and vegetation removal. According to DWA (2013) the overall PES for this SQ reach was a C Ecological Category.

The diatom results indicated that the water quality was good-high during June and August respectively and the SPI score was between 17.1 and 16.7 (A/B and B EC; Table 20.2). Nutrient and salinity levels were elevated but not problematic during sampling periods and remained relatively stable. The slight deterioration in the overall water quality condition could mainly be attributed to a slight increase in organic pollution levels as reflected by the PTV scores for June and August 2013 (Table 1.2). The outright dominance of *A. crassum* which prefers alkaline slow flowing streams limited accurate ecological interpretation.The diatom community consisted generally of species preferring moderate water quality conditions rather than good to high water quality conditions as indicator species for anthropogenic impacts were present albeit in low abundance. The other dominant species was *Encyonopsis leei* var. *sinensis* which occurs in slightly acidic, oligo- to mesotrophic waters with low to moderate electrolyte content (Taylor *et al*., 2007b).

Valve deformities were noted in both samples for June (2%) and August 2013 (1%) and fell within the threshold limit and indicated that metal toxicity was present at the time of sampling.

The PES for diatoms during June and August 2013 was generally in a B PES. However for the purposes of the Intermediate study the final PES was set at a B/C EC with an average score of 14.5 due to:

- The outright presence of *A. crassum;*
- the presence of indicator species for anthropogenic impacts; and
- the presence of valve deformities.

20.5.3 Mg_I_EWR2: uMngeni River

This site was sampled during June and August 2013 and is situated in the uMngeni River, SQ reach U20E-04243. Data availability was poor and the diatom assessment is based on the two samples collected during June and August 2013. SQ reach U20E-04243 was identified as a water quality hotspot, with large impacts relating to elevated nutrient loads; urban run-off from Howick (DWA, 2013). The Midmar Dam contributes to flow related problems in the reach. According to DWA (2013) the overall PES for this SQ reach was a C Ecological Category and this reach was identified as a hotspot.

The diatom results indicated that the water quality was moderate to good during June and August and the SPI score was 12.4 and 15.2 respectively (C and B EC; Table 20.2). During June 2013 the diatom community reflected typical moderate water quality conditions with dominant species preferring elevated nutrients (e.g. *C. placentula*) and organic pollution (e.g. *Gomphonema parvulum*). At the time of sampling nutrients were elevated with the potential of becoming problematic and oxygenation rates were high (Table 1.3). Organic pollution levels were elevated with PTVs making up 12.3% of the total count. Valve deformities were above threshold limits making up 3.75% of the total count and indicating that metal toxicity was present at the time of sampling.

During August 2013 the SPI score improved to 15.2 which may not have been a true reflection of current conditions at the time of sampling. This anomaly could be attributed to the outright dominance of *A. crassum*, which indicated an influx of water, although based on other dominant and sub-dominant species the water was of deteriorated quality. *E. minima*, *Fistulifera saprophila*, and *M. atomus* var. *permitis* were dominant and are characteristic of urban and sewage runoff and are the most pollution tolerant species. This is reflected by the notable increase in PTVs making up 28.5% of the total count. Organic pollution levels increased during August as well as nutrient levels, which was considered as problematic while salinity levels remained relatively stable.

Although valve deformities decreased a presence of 2.25% were still above threshold limits and indicated the presence of metal toxicity. As previously discussed the dominance of *E. minima* and the aerophilic *M. atomus* var. *permitis* indicated that sedimentation and fluctuating water levels would impact the instream biota in terms of general life cycles and breeding patterns.

The PES for diatoms during June and August 2013 was generally in a B/C PES. However for the purposes of the Intermediate study the final PES was set at a C/D EC with an average score of 12.2 due to:

- The outright presence of *A. crassum* during the August 2013 sample influencing the SPI score;
- the dominance of indicator species for anthropogenic impacts during August 2013; and
- the presence of valve deformities at abundances above threshold limits during June and August 2013.

20.5.4 Mg_I_EWR5: uMngeni River

This site was sampled during June and August 2013 and is situated in the uMngeni River, SQ reach U20L-04435. Data availability was moderate and the diatom assessment is based on the two samples collected during June and August 2013 as well as diatom information from the eThekwini Municipality - State of Rivers Report (SoR; GroundTruth, 2006) for the uMngeni River system. Additional diatom data from the 2006 SoR was available for:

- SQ U20G-04385: This SQ is situated upstream of EWR 5 and the site was identified as uMngenicauseway downstream of Nagle Dam and the diatoms determined that the biological water quality condition at the time was Fair (SPI score: 9 – 13) although it was noted that the score was influenced by recent flooding and spills from Nagle Dam.
- SQ U20M-04396: This SQ is situated downstream of EWR 5 and Inanda Dam and the site was identified as uMngeni upstream of the Mzinyati confluence and the diatoms determined that the biological water quality condition at the time was Natural (SPI score: >17) although it was noted that the score was influenced by recent flooding.
- SQ U20M-04543: This SQ is situated in the lower reaches of the uMngeni River in the area of Reservior Hills downstream of EWR 5 and Inanda Dam and the site was identified as uMngeni upstream of Silver Pipe and the diatoms determined that the biological water quality condition at the time was Good (SPI score: 13 - 17).

SQ reach U20L-04435 was identified as a water quality hotspot and general hotspot area, with large impacts relating to elevated nutrient loads and urban impacts (DWA, 2013). According to DWA (2013) the overall PES for this SQ reach was a B/C with flow related impacts originating from Nagel Dam and water quality issues originating from the Msunduze River.

On June 24, 2013 there was a spill at Howick WWTW, and the diatom sample was take between 23 – 27 June 2013. The diatom-based water quality conditions were generally of moderate water quality with a SPI score of 11.9 for June 2013 and 10.8 during August 2013. Nutrients and organic pollution levels remained relatively stable during June and August 2013 while the deterioration could mainly be attributed to elevated salinity levels which became problematic during August 2013. Dominant species observed during both months have a preference for elevated nutrient levels that could become problematic at times (e.g. *Cocconeis placentula* and *C. pediculus*). Although organic pollution levels were elevated but not problematic (PTVs made up 10 – 13% of the total count) (Table 20.2) the dominance of *Gomphonema* species indicated that organic pollution was present and could become problematic. *Mayamaea cahaebensis* was dominant during June 2013 and is a new species discovered in 2009 from Cahaba Valley Creek in the USA under eutrophic conditions. According to Morales and Manoylov (2009) the type locality of the species was warm water (22.9ºC) and slightly alkaline (pH 7.8) with concentration of orthophosphate-phosphorous of 0.12 mg/l and concentration nitrate and nitrite-nitrogen of 0.39 mg/l and conductivity of 248 uS/cm.

Navicula schroeteri var. *symmetrica* was abundant in both samples and becomes abundant in eutrophic, electrolyte rich waters and tolerant of strong pollution (Taylor *et al.*, 2007b). The sub-dominance of *E. minima* indicated increased sedimentation and aerophilic species were present indicating fluctuating water levels which would impact on the breeding and life cycles of instream biota.

Valve deformities made up 1% and 1.5% respectively of the total diatom count during June and August 2013 which fell below threshold limits and indicated the presence of metal toxicity at the time of sampling which most probably was due to the spill at the Howick WWTW.

Based on available information the diatom-based water quality was determined to be in a C/D Ecological Category and the water is characterised by elevated nutrient and salinity levels due to anthropogenic activities which include urban impacts.

20.5.5 Mk_I_EWR1: Mkomazi River

This site was only sampled during June 2013 and is situated in the Mkomazi River, SQ reach U10E-04380. Data availability was poor and the diatom assessment is based on the one sample collected during June 2013. According to DWA (2013) the overall PES for this SQ reach was a C Ecological Category mainly due to non-flow related impacts which included sedimentation, overgrazing and erosion.

The diatom based water quality was high with a SPI score of 17.7 (A/B Ecological Category). Nutrient, salinity and organic pollution levels were low and the diatom community was characterised by species preferring good water quality with a low tolerance for pollution. Dominant species included *E. leei* var. *sinensis* as well as *A. crassum* which had a dominance of nearly 50%.

No valve deformities were noted and the diatom PES was set at an A/B category based on the absence of pollution tolerant diatom species and valve deformities.

20.5.6 Mk_I_EWR2: Mkomazi River

This site was sampled during June and August 2013 and is situated in the Mkomazi River, SQ reach U10J-04679. Data availability was poor and the diatom assessment is based on the two samples collected during June and August 2013. SQ reach U10J-04679 was identified as a hotspot, due to future development and according to DWA (2013) the overall PES for this SQ reach was a B Ecological Category.

The diatom based water quality was high during June and August 2013 with a SPI score of 17.7 and 17.3 respectively. Nutrient and salinity levels were elevated but not problematic. Organic pollution levels were generally low and increased slightly during August 2013 with PTVs making up 1.8% of the total count compared to 0.5% during June 2013 (Table 20.2). Both samples were dominated by *Achnanthidium* species which included *A. crassum* and *A. minutissima*. *E. leei* var. *sinensis*was also dominant.

Overall the diatom community was reflective of high water quality with most species having a preference for these conditions. Due to the outright dominance of *A. crassum* ecological interpretation was limited. However pollution tolerant sub-dominant species were present and included *Eolimna minima*, *N. schroeteri* var. *symmetrica* and *Gomphonema* species which indicated that there was a measure of anthropogenic impact. The presence of valve deformities in the August 2013 sample at an occurrence of 1.25% indicated the presence of metal toxicity and would impact instream biota.

Due to the presence of valve deformities and the outright dominance of *A. crassum* the PES for this site was set at a B EC.

20.5.7 Mk_I_EWR3: Mkomazi River

This site was only sampled during August 2013 and is situated in the Mkomazi River, SQ reach U70E-04974. Data availability was good and the diatom assessment is based on the one sample collected during August 2013 as well as diatom information from the eThekwini Municipality - State of Rivers Report (SoR; GroundTruth, 2006) for the Mkomazi River system. Additional diatom data from the 2006 SoR was available for this SQ reach and included:

- A site downstream of EWR 3 was assessed downstream of Shozi weir and the diatoms determined that the biological water quality condition at the time was Natural (SPI score: >17).

- A site, Mkomaas @ Goodenough Barrage was assessed during 2006 and the diatoms determined that the biological water quality condition at the time was Natural (SPI score: >17).
- A site, Mkomaas @ SAPPI SAICCOR Barrage and the diatoms determined that the biological water quality condition at the time was Natural (SPI score: >17)

According to DWA (2013) the overall PES for this SQ reach was a C Ecological Category mainly due to flow related problems originating from a dam upstream of the EWR site and non-flow related impacts included rural settlements and grazing.

The diatom based water quality was high with a SPI score of 18.2 (A Ecological Category). Nutrient and salinity levels, as well as organic pollution levels were elevated but not problematic. The diatom community was dominated by the genus *Achnanthidium* which included *A. crissum, A. affine* and *A. minutissima*. *E. leei* var. *sinensis*was also dominant. Overall the diatom community was reflective of high water quality with most species having a preference for these conditions. The sub-dominance of *Navicula leptostriata* indicated that sedimentation could be impacting the reach.

Although valve deformities were noted the occurrence was very low and was not deemed problematic. Based on the available information the PES was set at an A/B Ecological Category due to the dominance of *Achnanthidium* species and sub-dominance of *F. capucina* var. *rumpens*, both pioneer species which may have been an indication that the periphyton community at the time of sampling was immature and therefore the biological water quality may not reflect the present conditions accurately. However the 2006 raw data indicated that *Achnanthidium* species were dominant at all three sites during the study and thus the continual dominance of this species could indicate that the water quality in this SQ reach is generally of high quality. Specialists at the workshop indicated that the flows in this section of the river were always high and this may account for the good water quality.

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21 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.

21.1 MV_I_EWR1

```
DATE: 07/22/2014
Revised Desktop Model outputs for site: Mv_I_EWR1

HYDROLOGY DATA SUMMARY
Natural Flows:                           Present Day Flows:
   Area     MAR   Ann.SD    Q75   Ann.     Area     MAR   Ann.SD    Q75   Ann.
  (km^2)      (m^3 * 10^6)        CV      (km^2)      (m^3 * 10^6)        CV
    0.00   17.36   11.35    0.42  0.65      0.00    7.08    7.97    0.11  1.13

% Zero flows =   0.0                     % Zero flows =   0.0
Baseflow Parameters: A = 0.955, B = 0.43Baseflow Parameters: A = 0.955, B = 0.430
BFI = 0.43 : Hydro Index =   4.0         BFI = 0.38 : Hydro Index =   7.6

MONTH   MEAN      SD     CV              MONTH   MEAN      SD     CV
        (m^3 * 10^6)                             (m^3 * 10^6)
 Oct    0.67    1.31    1.95              Oct    0.27    0.97    3.63
 Nov    0.80    0.71    0.89              Nov    0.21    0.28    1.33
 Dec    1.57    1.59    1.01              Dec    0.35    0.39    1.13
 Jan    2.50    3.02    1.21              Jan    0.93    1.69    1.82
 Feb    3.15    3.07    0.97              Feb    1.22    1.67    1.37
 Mar    3.26    3.66    1.12              Mar    1.54    3.06    1.99
 Apr    2.02    2.03    1.01              Apr    1.07    1.60    1.49
 May    1.11    0.76    0.68              May    0.54    0.64    1.19
 Jun    0.69    0.33    0.48              Jun    0.28    0.25    0.89
 Jul    0.48    0.24    0.50              Jul    0.16    0.15    0.88
 Aug    0.40    0.35    0.88              Aug    0.13    0.22    1.64
 Sep    0.71    2.88    4.04              Sep    0.38    2.32    6.11

Critical months: WET : Mar, DRY : Sep
Using  20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET :      0.528, DRY :      0.166

HYDRAULICS DATA SUMMARY
Geomorph. Zone  3
Flood Zone      8
Max. Channel width (m) 21.57
Max. Channel Depth (m)  2.24

Observed Channel XS used
Observed Rating Curve used
(Gradients and Roughness n values calibrated)

Max. Gradient         0.02400
Min. Gradient         0.01400
Gradient Shape Factor      20
Max. Mannings n         0.160
Min. Mannings n         0.058
n Shape Factor             60


FLOW - STRESSOR RESPONSE DATA SUMMARY
Table of Stress weightings
Season          Wet   Dry
```

Stress at 0 FS:	9	9
FS Weight:	4	2
FI Weight:	7	5
FD Weight:	9	7

Table of initial SHIFT factors for the Stress Frequency Curves

Category	High SHIFT	Low SHIFT
A	0.020	0.114
A/B	0.030	0.171
B	0.040	0.229
B/C	0.060	0.314
C	0.080	0.400
C/D	0.091	0.455
D	0.102	0.510

Perenniality Rules
All Seasons Perennial Forced

Alignment of maximum stress to Present Day stress
Not Aligned

Table of flows (m3/2) v stress index

Stress	Wet Season Flow	Dry Season Flow
0	0.574	0.181
1	0.520	0.175
2	0.460	0.166
3	0.390	0.150
4	0.315	0.120
5	0.232	0.070
6	0.135	0.040
7	0.057	0.022
8	0.011	0.011
9	0.003	0.003
10	0.000	0.000

HIGH FLOW ESTIMATION SUMMARY DETAILS
No High flows when natural high flows are < 30% of total flows
Adjusted hydrological variability for high flows is 0.02
Maximum high flows are 445% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

Category	A	A/B	B	B/C	C	C/D	D
Annual	0.858	0.848	0.835	0.820	0.803	0.783	0.760
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nov	0.095	0.094	0.093	0.091	0.089	0.087	0.084
Dec	0.136	0.135	0.133	0.130	0.128	0.124	0.121
Jan	0.196	0.193	0.190	0.187	0.183	0.178	0.173
Feb	0.169	0.167	0.164	0.162	0.158	0.154	0.150
Mar	0.148	0.146	0.144	0.141	0.138	0.135	0.131
Apr	0.114	0.113	0.111	0.109	0.107	0.104	0.101
May	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0.000

FINAL RESERVE SUMMARY DETAILS
EWR (low and total Flows) are constrained to be below Natural Flows

Long term mean flow requirements (Mill. m3 and %MAR)

Category	Low Flows		Total Flows	
	Mill. m3	%MAR	Mill. m3	%MAR
A	5.492	31.6	7.291	42.0
A/B	5.084	29.3	6.861	39.5
B	4.644	26.8	6.395	36.8
B/C	3.925	22.6	5.645	32.5

C	3.164	18.2	4.847	27.9
C/D	2.691	15.5	4.332	25.0
D	2.255	13.0	3.847	22.2

FINAL RESERVE SUMMARY DETAILS

EWR (low and total Flows) are constrained to be below Present Day Flows

Long term mean flow requirements (Mill. m3 and %MAR)

Category	Low Flows		Total Flows	
	Mill. m3	%MAR	Mill. m3	%MAR
A	4.161	24.0	4.897	28.2
A/B	3.999	23.0	4.819	27.8
B	3.802	21.9	4.712	27.1
B/C	3.425	19.7	4.472	25.8
C	2.930	16.9	4.102	23.6
C/D	2.569	14.8	3.800	21.9
D	2.197	12.7	3.463	20.0

FLOW DURATION and RESERVE ASSURANCE TABLES

Columns are FDC percentage points:

Natural Total flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	0.794	0.580	0.536	0.480	0.430	0.360	0.310	0.238	0.200	0.125
Nov	1.220	1.022	0.814	0.724	0.660	0.610	0.472	0.396	0.314	0.120
Dec	4.596	1.904	1.368	1.084	0.930	0.806	0.706	0.630	0.524	0.199
Jan	7.266	3.150	1.966	1.618	1.410	1.200	1.054	0.908	0.658	0.435
Feb	7.208	5.056	3.670	2.314	1.800	1.546	1.298	1.132	0.898	0.682
Mar	7.144	4.898	3.482	2.630	1.910	1.766	1.534	1.320	1.018	0.764
Apr	3.206	2.416	1.904	1.710	1.510	1.316	1.222	1.086	0.910	0.541
May	1.526	1.364	1.192	1.080	1.010	0.936	0.802	0.708	0.632	0.389
Jun	1.010	0.870	0.780	0.700	0.580	0.550	0.490	0.450	0.410	0.302
Jul	0.762	0.652	0.550	0.464	0.410	0.366	0.340	0.300	0.270	0.197
Aug	0.648	0.502	0.420	0.364	0.340	0.290	0.272	0.230	0.204	0.137
Sep	0.632	0.462	0.420	0.364	0.320	0.290	0.270	0.210	0.184	0.122

Natural Baseflow flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	0.521	0.431	0.379	0.336	0.306	0.281	0.239	0.200	0.192	0.125
Nov	0.583	0.482	0.439	0.398	0.370	0.317	0.281	0.236	0.220	0.120
Dec	1.148	0.773	0.555	0.478	0.442	0.390	0.341	0.307	0.252	0.143
Jan	1.622	1.000	0.783	0.644	0.524	0.481	0.429	0.364	0.302	0.187
Feb	1.747	1.308	1.069	0.863	0.749	0.601	0.555	0.456	0.387	0.251
Mar	1.694	1.396	1.133	0.998	0.868	0.750	0.620	0.570	0.447	0.342
Apr	1.377	1.255	1.050	0.902	0.785	0.721	0.643	0.574	0.484	0.357
May	1.146	1.008	0.867	0.768	0.710	0.645	0.610	0.522	0.445	0.299
Jun	0.902	0.795	0.698	0.614	0.580	0.520	0.470	0.428	0.376	0.279
Jul	0.692	0.601	0.542	0.460	0.400	0.360	0.340	0.300	0.270	0.197
Aug	0.590	0.467	0.398	0.357	0.340	0.290	0.271	0.230	0.204	0.137
Sep	0.500	0.422	0.371	0.320	0.290	0.276	0.242	0.210	0.180	0.122

Category Low Flow Assurance curves (mill. m3)

C Category

	10	20	30	40	50	60	70	80	90	99
Oct	0.212	0.142	0.130	0.110	0.100	0.080	0.070	0.060	0.050	0.030
Nov	0.292	0.223	0.187	0.162	0.138	0.114	0.100	0.080	0.060	0.020
Dec	0.544	0.365	0.256	0.209	0.175	0.151	0.137	0.128	0.094	0.035
Jan	0.788	0.493	0.380	0.289	0.220	0.191	0.177	0.153	0.124	0.070
Feb	0.791	0.600	0.499	0.378	0.286	0.228	0.212	0.178	0.164	0.120
Mar	0.780	0.692	0.591	0.484	0.390	0.323	0.275	0.238	0.212	0.145
Apr	0.681	0.585	0.512	0.419	0.332	0.298	0.256	0.230	0.211	0.107
May	0.560	0.486	0.425	0.358	0.305	0.277	0.252	0.210	0.158	0.077
Jun	0.433	0.373	0.318	0.230	0.190	0.170	0.152	0.128	0.104	0.075
Jul	0.260	0.212	0.168	0.144	0.120	0.110	0.100	0.090	0.080	0.055
Aug	0.186	0.150	0.120	0.110	0.090	0.080	0.080	0.070	0.060	0.040
Sep	0.176	0.130	0.110	0.100	0.090	0.080	0.070	0.060	0.050	0.030

D Category

	10	20	30	40	50	60	70	80	90	99
Oct	0.165	0.134	0.115	0.104	0.094	0.080	0.070	0.060	0.050	0.030
Nov	0.187	0.147	0.129	0.119	0.108	0.094	0.088	0.080	0.060	0.020

Dec	0.351	0.243	0.175	0.151	0.136	0.122	0.112	0.106	0.093	0.035
Jan	0.513	0.333	0.259	0.205	0.168	0.150	0.141	0.125	0.116	0.070
Feb	0.516	0.411	0.338	0.262	0.210	0.174	0.163	0.140	0.131	0.120
Mar	0.545	0.475	0.398	0.332	0.281	0.239	0.206	0.181	0.163	0.145
Apr	0.456	0.399	0.347	0.290	0.242	0.224	0.201	0.181	0.171	0.107
May	0.363	0.328	0.289	0.251	0.225	0.209	0.202	0.172	0.155	0.077
Jun	0.271	0.249	0.219	0.192	0.172	0.159	0.148	0.128	0.104	0.075
Jul	0.212	0.190	0.164	0.141	0.120	0.110	0.100	0.090	0.080	0.055
Aug	0.180	0.149	0.120	0.109	0.090	0.080	0.080	0.070	0.060	0.040
Sep	0.150	0.126	0.105	0.094	0.086	0.080	0.070	0.060	0.050	0.030

Category Total Flow Assurance curves (mill. m3)

C Category

Oct	0.212	0.142	0.130	0.110	0.100	0.080	0.070	0.060	0.050	0.030
Nov	0.292	0.252	0.188	0.164	0.140	0.130	0.100	0.080	0.060	0.020
Dec	0.720	0.470	0.330	0.254	0.210	0.180	0.150	0.130	0.094	0.035
Jan	1.586	0.896	0.610	0.392	0.360	0.286	0.240	0.186	0.124	0.070
Feb	1.481	1.259	1.118	0.854	0.444	0.375	0.312	0.247	0.166	0.120
Mar	1.383	1.268	1.131	0.961	0.528	0.452	0.378	0.298	0.214	0.145
Apr	1.148	1.031	0.930	0.788	0.439	0.398	0.336	0.276	0.213	0.107
May	0.560	0.486	0.425	0.358	0.305	0.277	0.252	0.210	0.158	0.077
Jun	0.433	0.373	0.318	0.230	0.190	0.170	0.152	0.128	0.104	0.075
Jul	0.260	0.212	0.168	0.144	0.120	0.110	0.100	0.090	0.080	0.055
Aug	0.186	0.150	0.120	0.110	0.090	0.080	0.080	0.070	0.060	0.040
Sep	0.176	0.130	0.110	0.100	0.090	0.080	0.070	0.060	0.050	0.030

D Category

Oct	0.165	0.134	0.115	0.104	0.094	0.080	0.070	0.060	0.050	0.030
Nov	0.292	0.252	0.188	0.164	0.140	0.130	0.100	0.080	0.060	0.020
Dec	0.720	0.470	0.330	0.254	0.210	0.180	0.150	0.130	0.094	0.035
Jan	1.269	0.896	0.610	0.392	0.341	0.286	0.240	0.186	0.118	0.070
Feb	1.169	1.035	0.923	0.779	0.360	0.314	0.275	0.206	0.133	0.120
Mar	1.115	1.019	0.909	0.783	0.412	0.361	0.304	0.238	0.165	0.145
Apr	0.897	0.820	0.742	0.639	0.344	0.318	0.276	0.226	0.173	0.107
May	0.363	0.328	0.289	0.251	0.225	0.209	0.202	0.172	0.155	0.077
Jun	0.271	0.249	0.219	0.192	0.172	0.159	0.148	0.128	0.104	0.075
Jul	0.212	0.190	0.164	0.141	0.120	0.110	0.100	0.090	0.080	0.055
Aug	0.180	0.149	0.120	0.109	0.090	0.080	0.080	0.070	0.060	0.040
Sep	0.150	0.126	0.105	0.094	0.086	0.080	0.070	0.060	0.050	0.030

21.2 MV_I_EWR2

TITLE: RDMR Report
DATE: 07/22/2014
Revised Desktop Model outputs for site: Mv_I_EWR2

HYDROLOGY DATA SUMMARY

Natural Flows:					Present Day Flows:				
Area	MAR	Ann.SD	Q75	Ann.	Area	MAR	Ann.SD	Q75	Ann.
(km^2)	(m^3 * 10^6)			CV	(km^2)	(m^3 * 10^6)			CV
0.00	273.96	174.01	6.23	0.64	0.00	168.84	142.08	2.67	0.84

% Zero flows = 0.0 % Zero flows = 0.0
Baseflow Parameters: A = 0.955, B = 0.43Baseflow Parameters: A = 0.955, B = 0.430
BFI = 0.42 : Hydro Index = 4.9 BFI = 0.37 : Hydro Index = 7.5

MONTH	MEAN	SD	CV	MONTH	MEAN	SD	CV
	(m^3 * 10^6)				(m^3 * 10^6)		
Oct	14.72	27.12	1.84	Oct	9.63	23.10	2.40
Nov	18.83	16.17	0.86	Nov	11.52	12.57	1.09
Dec	28.62	29.96	1.05	Dec	15.51	18.36	1.18
Jan	37.03	34.90	0.94	Jan	20.07	21.51	1.07
Feb	45.46	43.12	0.95	Feb	27.41	29.52	1.08
Mar	48.87	60.57	1.24	Mar	33.13	54.82	1.65
Apr	27.97	27.67	0.99	Apr	19.37	24.41	1.26
May	16.01	17.57	1.10	May	10.25	14.21	1.39
Jun	9.71	8.46	0.87	Jun	5.56	7.03	1.26
Jul	6.47	3.96	0.61	Jul	3.24	3.06	0.94
Aug	6.42	10.13	1.58	Aug	3.29	7.50	2.28

Sep	13.86	59.21	4.27	Sep	9.85	53.35	5.42

Critical months: WET : Mar, DRY : Sep
Using 20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET : 7.828, DRY : 2.438

HYDRAULICS DATA SUMMARY
Geomorph. Zone 3
Flood Zone 8
Max. Channel width (m) 54.11
Max. Channel Depth (m) 2.70

Observed Channel XS used
Observed Rating Curve used
(Gradients and Roughness n values calibrated)

Max. Gradient	0.00800
Min. Gradient	0.00800
Gradient Shape Factor	20
Max. Mannings n	0.080
Min. Mannings n	0.041
n Shape Factor	20

FLOW - STRESSOR RESPONSE DATA SUMMARY
Table of Stress weightings

Season	Wet	Dry
Stress at 0 FS:	9	9
FS Weight:	4	2
FI Weight:	7	5
FD Weight:	9	7

Table of initial SHIFT factors for the Stress Frequency Curves

Category	High SHIFT	Low SHIFT
A	0.113	0.076
A/B	0.170	0.115
B	0.227	0.153
B/C	0.340	0.210
C	0.453	0.267
C/D	0.567	0.305
D	0.680	0.382

Perenniality Rules
All Seasons Perennial Forced

Alignment of maximum stress to Present Day stress
Not Aligned

Table of flows (m3/2) v stress index

	Wet Season	Dry Season
Stress	Flow	Flow
0	7.975	2.482
1	5.486	2.200
2	3.700	1.850
3	2.700	1.450
4	2.000	1.000
5	1.440	0.650
6	0.950	0.400
7	0.600	0.210
8	0.300	0.100
9	0.111	0.030
10	0.000	0.000

HIGH FLOW ESTIMATION SUMMARY DETAILS
No High flows when natural high flows are < 20% of total flows
Adjusted hydrological variability for high flows is 0.29
Maximum high flows are 178% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

Category	A	A/B	B	B/C	C	C/D	D
Annual	21.924	21.087	20.226	19.340	18.429	17.493	16.530
Oct	1.406	1.352	1.297	1.240	1.182	1.122	1.060
Nov	3.183	3.061	2.936	2.808	2.675	2.539	2.400
Dec	3.550	3.414	3.275	3.131	2.984	2.832	2.676
Jan	4.463	4.293	4.118	3.937	3.752	3.561	3.365
Feb	3.761	3.618	3.470	3.318	3.162	3.001	2.836
Mar	3.387	3.258	3.125	2.988	2.847	2.702	2.554
Apr	2.174	2.091	2.005	1.918	1.827	1.734	1.639
May	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0.000

FINAL RESERVE SUMMARY DETAILS

EWR (low and total Flows) are constrained to be below Present Day Flows

Long term mean flow requirements (Mill. m3 and %MAR)

Category	Low Flows		Total Flows	
	Mill. m3	%MAR	Mill. m3	%MAR
A	70.125	25.6	91.093	33.3
A/B	63.640	23.2	84.388	30.8
B	57.503	21.0	77.656	28.3
B/C	48.279	17.6	67.726	24.7
C	39.525	14.4	58.056	21.2
C/D	33.378	12.2	50.967	18.6
D	24.815	9.1	41.436	15.1

FLOW DURATION and RESERVE ASSURANCE TABLES

Columns are FDC percentage points:

Natural Total flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	22.236	12.926	10.894	9.440	7.760	6.316	5.796	4.560	3.628	1.914
Nov	48.620	24.926	21.046	15.234	13.250	11.896	10.014	7.882	5.762	2.328
Dec	56.490	38.564	28.434	21.140	17.380	14.882	13.692	10.750	7.506	3.500
Jan	95.084	59.430	34.606	30.064	25.670	19.738	15.836	12.384	8.636	6.717
Feb	91.320	76.064	50.444	35.712	28.510	23.706	18.958	15.928	12.648	7.502
Mar	104.520	66.450	44.728	37.092	29.700	25.724	23.090	17.118	13.824	7.926
Apr	45.534	35.744	28.176	24.740	21.250	18.892	16.496	13.382	10.724	5.603
May	22.552	17.698	16.532	14.796	12.310	11.600	9.806	8.478	7.172	4.416
Jun	16.468	11.558	9.636	8.612	8.070	6.632	6.210	5.450	4.720	3.127
Jul	11.910	9.224	7.708	5.516	4.990	4.586	4.188	3.686	3.204	2.190
Aug	10.310	8.054	5.836	5.164	4.620	3.994	3.608	3.136	2.554	1.768
Sep	12.290	7.906	6.946	6.262	5.110	4.712	4.140	3.136	2.522	1.715

Natural Baseflow flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	9.122	6.775	6.316	5.641	4.955	4.336	3.687	3.255	2.964	1.788
Nov	14.004	9.072	7.330	6.671	6.043	5.580	4.721	4.085	3.383	1.811
Dec	19.362	12.670	10.839	7.948	7.397	6.652	5.574	5.204	3.822	1.942
Jan	22.406	18.171	13.388	10.509	9.137	8.353	7.144	5.612	4.827	2.818
Feb	25.633	19.252	16.455	14.075	11.653	9.844	8.664	6.900	5.880	3.909
Mar	26.235	20.909	17.445	14.715	13.036	11.721	11.042	8.346	6.598	4.483
Apr	20.457	18.444	15.523	12.732	11.698	11.208	10.005	8.224	6.724	4.696
May	17.566	14.789	13.256	10.470	9.925	9.406	8.798	7.510	5.855	3.952
Jun	12.948	10.868	9.018	8.488	7.550	6.604	6.090	5.244	4.643	3.127
Jul	9.876	8.832	6.826	5.425	4.990	4.586	4.188	3.686	3.204	2.190
Aug	8.976	6.844	5.244	5.007	4.254	3.852	3.583	3.078	2.554	1.768
Sep	7.422	6.115	5.458	4.824	4.157	3.805	3.340	2.924	2.522	1.715

Category Low Flow Assurance curves (mill. m3)

B/C Category

	10	20	30	40	50	60	70	80	90	99
Oct	5.394	4.346	3.810	3.037	2.356	1.707	1.270	1.008	0.838	0.387
Nov	6.700	5.402	4.333	3.468	2.796	2.174	1.642	1.291	1.011	0.716
Dec	8.342	7.135	5.911	4.364	3.546	2.765	2.117	1.757	1.304	0.984
Jan	9.007	8.464	7.167	5.579	4.547	3.589	2.677	1.996	1.711	1.288
Feb	9.632	8.320	7.415	6.512	5.256	4.018	3.117	2.459	2.022	1.716
Mar	9.404	9.069	8.473	7.542	6.547	5.434	4.429	3.493	2.709	2.218

Apr	8.905	8.332	7.607	6.599	5.644	4.904	3.995	3.231	2.329	1.621
May	8.171	7.770	6.958	5.626	4.866	4.167	3.475	2.924	2.321	1.187
Jun	6.632	6.064	5.074	4.334	3.529	2.644	2.158	1.802	1.523	0.813
Jul	5.681	5.315	3.646	2.514	2.030	1.838	1.448	1.158	0.975	0.404
Aug	5.072	3.958	2.712	2.300	1.930	1.547	1.208	0.969	0.764	0.337
Sep	4.396	3.934	3.267	2.510	1.897	1.432	1.082	0.856	0.689	0.357

C/D Category

Oct	4.094	3.107	2.564	1.942	1.427	0.949	0.623	0.465	0.362	0.268
Nov	5.022	3.882	2.944	2.255	1.740	1.267	0.858	0.637	0.465	0.367
Dec	6.250	5.165	4.110	2.910	2.280	1.678	1.165	0.928	0.637	0.442
Jan	6.706	6.201	5.115	3.867	3.062	2.302	1.563	1.086	0.895	0.616
Feb	7.225	6.128	5.422	4.742	3.733	2.704	1.939	1.440	1.128	0.898
Mar	6.962	6.715	6.274	5.586	4.778	3.842	2.927	2.165	1.580	1.199
Apr	6.678	6.120	5.528	4.764	4.007	3.400	2.599	1.956	1.232	1.129
May	6.094	5.654	4.942	3.905	3.321	2.761	2.163	1.740	1.305	1.007
Jun	4.972	4.370	3.488	2.899	2.282	1.599	1.201	0.964	0.778	0.694
Jul	4.266	3.814	2.898	1.926	1.430	1.033	0.730	0.552	0.436	0.395
Aug	3.818	3.120	2.038	1.699	1.218	0.869	0.587	0.450	0.402	0.278
Sep	3.348	2.798	2.185	1.583	1.120	0.774	0.514	0.382	0.280	0.228

Category Total Flow Assurance curves (mill. m3)

B/C Category

Oct	7.535	6.341	5.641	4.659	3.596	2.866	2.199	1.549	0.857	0.387
Nov	11.546	9.920	8.476	7.139	5.603	4.798	3.744	2.516	1.054	0.716
Dec	13.746	12.174	10.531	8.458	6.677	5.692	4.461	3.123	1.352	0.984
Jan	15.802	14.800	12.976	10.727	8.484	7.268	5.625	3.713	1.771	1.288
Feb	15.358	13.659	12.311	10.850	8.574	7.119	5.601	3.907	2.072	1.716
Mar	14.560	13.877	12.882	11.448	9.535	8.226	6.666	4.796	2.754	2.218
Apr	12.214	11.418	10.437	9.107	7.562	6.696	5.431	4.067	2.358	1.621
May	8.171	7.770	6.958	5.626	4.866	4.167	3.475	2.924	2.321	1.187
Jun	6.632	6.064	5.074	4.334	3.529	2.644	2.158	1.802	1.523	0.813
Jul	5.681	5.315	3.646	2.514	2.030	1.838	1.448	1.158	0.975	0.404
Aug	5.072	3.958	2.712	2.300	1.930	1.547	1.208	0.969	0.764	0.337
Sep	4.396	3.934	3.267	2.510	1.897	1.432	1.082	0.856	0.689	0.357

C/D Category

Oct	6.030	4.912	4.220	3.409	2.549	1.997	1.463	0.955	0.379	0.268
Nov	9.405	7.968	6.691	5.576	4.280	3.640	2.759	1.745	0.504	0.367
Dec	11.138	9.723	8.289	6.613	5.113	4.325	3.285	2.163	0.680	0.442
Jan	12.852	11.931	10.370	8.523	6.623	5.630	4.229	2.639	0.950	0.616
Feb	12.405	10.957	9.851	8.666	6.734	5.509	4.186	2.749	1.174	0.898
Mar	11.625	11.063	10.262	9.119	7.481	6.367	4.950	3.344	1.621	1.199
Apr	9.671	8.911	8.088	7.031	5.741	5.021	3.897	2.712	1.258	1.129
May	6.094	5.654	4.942	3.905	3.321	2.761	2.163	1.740	1.305	1.007
Jun	4.972	4.370	3.488	2.899	2.282	1.599	1.201	0.964	0.778	0.694
Jul	4.266	3.814	2.898	1.926	1.430	1.033	0.730	0.552	0.436	0.395
Aug	3.818	3.120	2.038	1.699	1.218	0.869	0.587	0.450	0.402	0.278
Sep	3.348	2.798	2.185	1.583	1.120	0.774	0.514	0.382	0.280	0.228

21.3 MG_I_EWR2

DATE: 07/22/2014
Revised Desktop Model outputs for site: Mg_I_EWR2

HYDROLOGY DATA SUMMARY

Natural Flows:					Present Day Flows:				
Area	MAR	Ann.SD	Q75	Ann.	Area	MAR	Ann.SD	Q75	Ann.
(km^2)	(m^3 * 10^6)			CV	(km^2)	(m^3 * 10^6)			CV
0.00	228.19	112.97	6.39	0.50	0.00	105.40	85.44	2.20	0.81

% Zero flows = 0.0 % Zero flows = 0.0
Baseflow Parameters: A = 0.955, B = 0.43Baseflow Parameters: A = 0.955, B = 0.430
BFI = 0.46 : Hydro Index = 3.1 BFI = 0.42 : Hydro Index = 5.2

MONTH	MEAN	SD	CV	MONTH	MEAN	SD	CV
	(m^3 * 10^6)				(m^3 * 10^6)		
Oct	12.42	15.93	1.28	Oct	4.75	11.70	2.46
Nov	16.43	12.79	0.78	Nov	4.50	8.49	1.89

Dec	26.65	25.09	0.94	Dec	9.37	14.28	1.52
Jan	32.94	26.66	0.81	Jan	16.28	23.12	1.42
Feb	38.44	30.08	0.78	Feb	21.59	26.61	1.23
Mar	35.82	24.79	0.69	Mar	20.72	23.04	1.11
Apr	22.29	16.34	0.73	Apr	10.93	14.38	1.32
May	12.66	10.15	0.80	May	4.90	7.92	1.62
Jun	8.04	4.45	0.55	Jun	2.73	1.68	0.61
Jul	7.00	4.97	0.71	Jul	2.77	2.69	0.97
Aug	6.56	5.34	0.81	Aug	2.72	3.23	1.19
Sep	8.93	20.10	2.25	Sep	4.14	15.28	3.69

Critical months: WET : Feb, DRY : Sep
Using 20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET : 6.920, DRY : 2.600

HYDRAULICS DATA SUMMARY
Geomorph. Zone 3
Flood Zone 8
Max. Channel width (m) 42.85
Max. Channel Depth (m) 5.72

Observed Channel XS used
Observed Rating Curve used
(Gradients and Roughness n values calibrated)

Max. Gradient	0.00990
Min. Gradient	0.00500
Gradient Shape Factor	20
Max. Mannings n	0.110
Min. Mannings n	0.070
n Shape Factor	80

FLOW - STRESSOR RESPONSE DATA SUMMARY
Table of Stress weightings

Season	Wet	Dry
Stress at 0 FS:	9	9
FS Weight:	4	2
FI Weight:	7	5
FD Weight:	9	7

Table of initial SHIFT factors for the Stress Frequency Curves

Category	High SHIFT	Low SHIFT
A	0.000	0.097
A/B	0.000	0.146
B	0.000	0.194
B/C	0.000	0.267
C	0.000	0.340
C/D	0.000	0.389
D	0.000	0.486

Perenniality Rules
All Seasons Perennial Forced

Alignment of maximum stress to Present Day stress
Not Aligned

Table of flows (m3/2) v stress index

Stress	Wet Season Flow	Dry Season Flow
0	6.956	2.698
1	5.500	2.199
2	3.000	1.750
3	2.000	1.350
4	1.300	1.000
5	0.836	0.675
6	0.558	0.436
7	0.355	0.304
8	0.182	0.180

9	0.092	0.080
10	0.000	0.000

HIGH FLOW ESTIMATION SUMMARY DETAILS

No High flows when natural high flows are < 20% of total flows
Adjusted hydrological variability for high flows is 0.02
Maximum high flows are 298% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

Category	A	A/B	B	B/C	C	C/D	D
Annual	11.284	11.148	10.982	10.786	10.557	10.292	9.989
Oct	0.702	0.693	0.683	0.671	0.656	0.640	0.621
Nov	1.530	1.511	1.489	1.462	1.431	1.395	1.354
Dec	1.917	1.894	1.866	1.832	1.793	1.748	1.697
Jan	2.337	2.309	2.275	2.234	2.186	2.132	2.069
Feb	1.973	1.949	1.921	1.886	1.846	1.800	1.747
Mar	1.837	1.815	1.788	1.756	1.719	1.676	1.626
Apr	0.988	0.976	0.961	0.944	0.924	0.901	0.874
May	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0.000

FINAL RESERVE SUMMARY DETAILS

EWR (low and total Flows) are constrained to be below Present Day Flows

Long term mean flow requirements (Mill. m3 and %MAR)

Category	Low Flows		Total Flows	
	Mill. m3	%MAR	Mill. m3	%MAR
A	54.258	23.8	63.994	28.0
A/B	48.501	21.3	58.824	25.8
B	43.603	19.1	54.270	23.8
B/C	38.453	16.9	49.883	21.9
C	33.503	14.7	45.610	20.0
C/D	30.003	13.1	42.456	18.6
D	22.581	9.9	35.866	15.7

FLOW DURATION and RESERVE ASSURANCE TABLES

Columns are FDC percentage points:

Natural Total flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	25.220	13.292	10.709	8.872	7.905	6.778	5.979	4.918	3.958	2.624
Nov	34.190	20.370	17.396	15.196	13.025	11.444	9.281	7.552	6.014	2.931
Dec	54.271	41.162	27.014	24.062	19.680	15.812	12.154	8.432	6.824	3.537
Jan	72.886	46.572	35.892	31.836	26.000	21.476	17.871	12.556	8.962	3.278
Feb	82.788	60.942	44.102	34.696	27.790	24.306	19.356	16.486	11.204	2.446
Mar	68.846	47.898	40.712	33.364	28.795	26.068	24.222	18.132	12.457	4.129
Apr	39.453	30.274	24.345	20.478	19.215	16.500	14.037	12.902	8.662	3.628
May	17.170	15.192	14.113	12.084	10.930	9.852	8.192	7.652	5.870	2.545
Jun	12.729	9.904	8.800	8.152	7.620	6.692	5.714	4.996	4.015	1.739
Jul	12.602	8.700	7.517	6.860	6.215	5.056	4.380	3.608	3.006	1.815
Aug	9.727	8.550	7.606	6.426	5.745	4.944	4.037	3.718	2.426	1.971
Sep	11.345	9.548	7.587	6.004	5.705	5.148	4.183	3.314	2.547	1.580

Natural Baseflow flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	9.433	7.819	6.362	5.746	5.173	4.752	3.861	3.545	2.759	1.587
Nov	10.175	9.031	7.869	6.939	6.251	5.624	5.004	4.154	3.247	2.226
Dec	16.675	11.591	10.134	8.736	7.934	6.836	6.304	5.488	3.705	2.699
Jan	20.656	14.713	12.921	10.863	9.504	7.974	7.401	6.190	4.348	2.558
Feb	25.378	16.724	14.931	12.642	11.626	10.251	8.575	7.567	5.825	2.446
Mar	22.205	16.401	14.265	13.456	12.513	11.675	10.253	8.257	7.027	3.452
Apr	18.665	14.428	13.494	12.433	11.417	10.461	9.112	7.729	6.152	3.415
May	15.776	12.383	11.660	10.329	9.121	8.318	7.443	6.184	5.117	2.545
Jun	12.010	9.778	8.224	7.951	7.130	6.261	5.602	4.870	4.015	1.739
Jul	11.359	7.999	7.431	6.602	5.961	5.056	4.380	3.608	3.006	1.525
Aug	8.970	7.694	6.746	5.770	5.230	4.722	3.996	3.141	2.325	1.624

Sep	8.730	6.724	5.890	5.524	4.917	4.450	3.745	2.892	2.404	1.373

Category Low Flow Assurance curves (mill. m3)
C Category

Oct	3.444	2.606	2.384	2.336	2.240	2.192	1.912	1.679	1.380	0.875
Nov	3.581	3.378	2.670	2.454	2.370	2.274	2.088	1.788	1.589	1.527
Dec	4.530	4.263	4.004	3.607	3.178	2.767	2.289	1.921	1.755	1.258
Jan	4.628	4.401	4.162	3.759	3.347	2.845	2.288	1.877	1.489	1.375
Feb	4.041	3.915	3.690	3.327	2.907	2.416	1.889	1.464	1.105	0.687
Mar	5.482	5.471	5.460	5.375	4.984	4.386	3.725	3.240	2.559	1.751
Apr	4.471	4.363	4.361	4.360	3.827	3.591	3.271	2.771	2.188	1.019
May	4.419	4.264	4.088	3.500	3.100	2.742	2.282	1.852	1.563	1.225
Jun	3.275	2.928	2.677	2.590	2.395	2.286	2.142	1.840	1.399	0.906
Jul	2.840	2.620	2.514	2.436	2.345	2.288	2.010	1.729	1.356	1.016
Aug	2.860	2.538	2.400	2.336	2.310	2.234	1.801	1.567	1.106	1.081
Sep	2.613	2.338	2.258	2.176	2.140	2.100	1.762	1.464	1.195	1.023

Category Total Flow Assurance curves (mill. m3)
C Category

Oct	5.357	2.606	2.384	2.336	2.240	2.192	2.106	1.844	1.384	0.875
Nov	5.526	3.378	2.670	2.454	2.370	2.274	2.166	2.032	1.598	1.527
Dec	9.788	9.318	5.678	3.774	3.185	2.786	2.501	2.240	1.765	1.258
Jan	11.038	10.563	10.000	8.242	5.540	4.554	3.400	2.638	1.502	1.375
Feb	9.453	9.118	8.620	7.767	4.843	4.141	3.270	2.269	1.116	0.687
Mar	10.521	10.316	10.050	9.510	6.786	5.992	5.011	3.989	2.570	1.751
Apr	7.180	6.967	6.829	6.583	4.796	4.455	3.664	2.794	2.194	1.019
May	4.419	4.264	4.088	3.500	3.100	2.742	2.282	1.852	1.563	1.225
Jun	3.275	2.928	2.677	2.590	2.395	2.286	2.142	1.840	1.399	0.906
Jul	2.840	2.620	2.514	2.436	2.345	2.288	2.010	1.729	1.356	1.016
Aug	2.860	2.538	2.400	2.336	2.310	2.234	1.801	1.567	1.106	1.081
Sep	2.613	2.338	2.258	2.176	2.140	2.100	1.762	1.464	1.195	1.023

21.4 MG_I_EWR5

DATE: 07/22/2014
Revised Desktop Model outputs for site: Mg_I_EWR5

HYDROLOGY DATA SUMMARY

Natural Flows:					Present Day Flows:				
Area	MAR	Ann.SD	Q75	Ann.	Area	MAR	Ann.SD	Q75	Ann.
(km^2)	(m^3 * 10^6)			CV	(km^2)	(m^3 * 10^6)			CV
0.00	583.66	322.17	14.96	0.55	0.00	245.25	210.29	6.77	0.86

% Zero flows =   0.0   % Zero flows =   0.0
Baseflow Parameters: A = 0.955, B = 0.43Baseflow Parameters: A = 0.955, B = 0.430
BFI = 0.45 : Hydro Index =   3.6   BFI = 0.47 : Hydro Index =   4.8

MONTH	MEAN	SD	CV	MONTH	MEAN	SD	CV
	(m^3 * 10^6)				(m^3 * 10^6)		
Oct	30.67	51.47	1.68	Oct	14.74	35.64	2.42
Nov	40.35	39.17	0.97	Nov	14.04	25.79	1.84
Dec	65.93	66.47	1.01	Dec	22.02	30.29	1.38
Jan	81.63	66.19	0.81	Jan	28.97	39.71	1.37
Feb	99.60	79.27	0.80	Feb	43.55	60.17	1.38
Mar	91.38	68.18	0.75	Mar	41.67	52.26	1.25
Apr	58.61	50.49	0.86	Apr	25.62	38.75	1.51
May	34.61	33.92	0.98	May	14.07	24.03	1.71
Jun	21.55	14.94	0.69	Jun	9.05	6.85	0.76
Jul	17.26	12.54	0.73	Jul	8.05	5.81	0.72
Aug	16.07	17.80	1.11	Aug	8.11	10.75	1.32
Sep	25.98	89.43	3.44	Sep	15.36	68.75	4.48

Critical months: WET : Feb, DRY : Sep
Using 20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET :   19.244, DRY :   6.435

HYDRAULICS DATA SUMMARY
Geomorph. Zone 3
Flood Zone   8

Max. Channel width (m) 64.88
Max. Channel Depth (m) 2.68

Observed Channel XS used
Observed Rating Curve used
(Gradients and Roughness n values calibrated)

Max. Gradient	0.01100
Min. Gradient	0.01100
Gradient Shape Factor	20
Max. Mannings n	0.300
Min. Mannings n	0.053
n Shape Factor	48

FLOW - STRESSOR RESPONSE DATA SUMMARY

Table of Stress weightings

Season	Wet	Dry
Stress at 0 FS:	9	9
FS Weight:	4	2
FI Weight:	7	5
FD Weight:	9	7

Table of initial SHIFT factors for the Stress Frequency Curves

Category	High SHIFT	Low SHIFT
A	0.144	0.016
A/B	0.216	0.024
B	0.288	0.033
B/C	0.432	0.045
C	0.576	0.057
C/D	0.720	0.065
D	0.864	0.081

Perenniality Rules
All Seasons Perennial Forced

Alignment of maximum stress to Present Day stress
Not Aligned

Table of flows (m3/2) v stress index

Stress	Wet Season Flow	Dry Season Flow
0	19.253	6.618
1	15.000	4.800
2	5.000	3.313
3	3.000	2.200
4	2.100	1.600
5	1.580	1.079
6	1.079	0.733
7	0.800	0.539
8	0.550	0.350
9	0.270	0.184
10	0.000	0.000

HIGH FLOW ESTIMATION SUMMARY DETAILS

No High flows when natural high flows are < 20% of total flows
Adjusted hydrological variability for high flows is 0.16
Maximum high flows are 100% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

Category	A	A/B	B	B/C	C	C/D	D
Annual	41.966	40.605	39.180	37.687	36.127	34.495	32.791
Oct	1.670	1.616	1.559	1.500	1.437	1.373	1.305
Nov	5.404	5.229	5.046	4.853	4.652	4.442	4.223
Dec	7.265	7.030	6.783	6.525	6.254	5.972	5.677
Jan	8.370	8.099	7.814	7.517	7.205	6.880	6.540
Feb	8.068	7.806	7.532	7.245	6.945	6.632	6.304
Mar	7.501	7.258	7.003	6.736	6.457	6.165	5.861
Apr	3.688	3.568	3.443	3.312	3.174	3.031	2.881

May	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0.000

FINAL RESERVE SUMMARY DETAILS

EWR (low and total Flows) are constrained to be below Present Day Flows

Long term mean flow requirements (Mill. m3 and %MAR)

Category	Low Flows		Total Flows	
	Mill. m3	%MAR	Mill. m3	%MAR
A	160.917	27.6	168.722	28.9
A/B	159.204	27.3	167.451	28.7
B	156.509	26.8	165.853	28.4
B/C	149.850	25.7	162.411	27.8
C	141.296	24.2	156.562	26.8
C/D	133.571	22.9	150.588	25.8
D	123.465	21.2	141.814	24.3

FLOW DURATION and RESERVE ASSURANCE TABLES

Columns are FDC percentage points:

Natural Total flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	47.235	27.230	23.294	19.432	16.485	14.422	12.930	11.078	9.491	6.523
Nov	76.219	51.572	39.679	33.416	28.385	24.986	21.166	17.824	13.664	8.373
Dec	131.461	107.992	72.811	50.336	42.695	34.274	30.670	24.350	17.187	8.442
Jan	177.435	116.952	95.965	81.228	64.480	53.336	38.905	29.632	20.905	14.824
Feb	228.198	147.724	118.344	96.766	75.685	58.318	50.566	35.432	30.928	9.194
Mar	176.359	135.994	115.312	82.204	74.905	66.358	51.937	39.630	32.246	13.946
Apr	105.626	89.126	66.069	53.660	47.045	39.572	33.356	30.218	22.562	9.524
May	50.936	40.652	35.222	32.360	28.370	25.096	21.055	19.284	13.150	6.702
Jun	29.364	25.730	22.526	21.038	19.600	17.456	14.688	12.880	10.518	5.401
Jul	32.186	20.978	17.421	16.392	14.760	13.204	10.871	9.700	8.462	4.927
Aug	23.749	19.656	16.509	14.354	12.990	11.620	9.842	8.752	6.822	5.762
Sep	23.575	19.488	17.297	14.608	13.050	11.578	10.280	8.824	7.076	4.869

Natural Baseflow flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	22.849	17.552	15.231	13.380	11.962	10.516	9.754	8.586	7.135	5.122
Nov	25.825	21.360	18.496	15.654	13.982	12.415	11.553	10.308	8.461	6.065
Dec	40.412	31.129	26.074	18.943	17.880	15.785	14.383	11.730	9.569	7.210
Jan	53.599	39.621	31.387	26.669	24.162	21.145	17.650	14.240	10.543	8.173
Feb	58.859	46.223	34.348	30.750	28.701	26.831	22.210	17.570	13.185	9.045
Mar	51.945	45.181	38.370	34.007	30.594	27.052	24.815	20.801	16.606	9.446
Apr	44.843	39.746	34.051	31.199	27.317	25.240	23.522	19.919	14.300	9.095
May	37.141	32.758	29.145	25.393	23.472	22.310	19.196	16.304	12.985	6.702
Jun	28.014	23.466	22.233	20.904	18.600	16.924	13.834	12.172	10.299	5.401
Jul	24.864	20.610	17.318	16.300	14.420	12.545	10.745	9.633	8.378	4.800
Aug	21.477	18.114	14.818	13.468	11.930	11.214	9.610	8.632	6.726	4.982
Sep	19.054	16.536	13.521	12.783	11.500	10.567	9.234	7.518	6.452	4.722

Category Low Flow Assurance curves (mill. m3)

C/D Category

	10	20	30	40	50	60	70	80	90	99
Oct	12.025	9.002	8.509	7.746	7.415	4.913	4.812	3.855	2.990	2.607
Nov	18.111	9.964	9.511	8.782	8.425	6.563	5.184	4.222	3.452	2.948
Dec	30.736	24.444	13.068	9.966	9.305	7.592	5.975	4.801	3.892	3.452
Jan	34.704	29.880	21.873	13.535	10.481	8.084	6.411	5.136	4.246	4.195
Feb	37.592	31.215	20.351	11.236	8.620	6.738	5.716	4.943	4.532	4.160
Mar	36.424	34.189	29.607	20.635	15.531	10.542	9.593	7.962	6.659	5.434
Apr	32.213	29.401	18.663	13.212	9.944	8.249	8.248	7.168	5.532	4.414
May	14.779	12.846	11.483	9.986	9.250	8.073	6.502	5.406	4.731	3.558
Jun	10.468	9.826	8.937	8.040	7.800	7.230	5.739	4.654	3.843	2.944
Jul	10.286	8.822	7.933	7.222	6.970	6.744	5.113	4.144	3.406	2.781
Aug	9.614	8.496	7.537	6.890	6.545	6.034	4.145	3.770	2.880	2.675
Sep	9.467	8.646	7.414	7.010	6.670	5.756	4.485	3.420	2.630	2.222

Category Total Flow Assurance curves (mill. m3)
C/D Category

Oct	12.025	9.002	8.509	7.746	7.415	6.196	5.839	4.453	2.998	2.607
Nov	21.377	9.964	9.511	8.782	8.425	7.980	7.220	6.159	3.478	2.948
Dec	36.708	26.686	13.068	9.966	9.305	8.870	8.278	7.405	3.928	3.452
Jan	41.584	35.878	24.267	17.016	12.005	10.378	9.526	8.085	4.287	4.195
Feb	44.223	37.847	26.983	17.868	15.237	12.934	10.677	7.835	4.571	4.160
Mar	42.589	40.354	35.772	26.800	21.656	15.414	12.071	10.583	6.695	5.434
Apr	35.244	32.432	18.663	13.212	11.490	10.846	9.754	8.490	5.550	4.414
May	14.779	12.846	11.483	9.986	9.250	8.073	6.502	5.406	4.731	3.558
Jun	10.468	9.826	8.937	8.040	7.800	7.230	5.739	4.654	3.843	2.944
Jul	10.286	8.822	7.933	7.222	6.970	6.744	5.113	4.144	3.406	2.781
Aug	9.614	8.496	7.537	6.890	6.545	6.034	4.145	3.770	2.880	2.675
Sep	9.467	8.646	7.414	7.010	6.670	5.756	4.485	3.420	2.630	2.222

21.5 MK_I_EWR1

DATE: 05/15/2014
Revised Desktop Model outputs for site: Mk_I_EWR1

HYDROLOGY DATA SUMMARY

Natural Flows:					Present Day Flows:				
Area (km^2)	MAR (m^3 * 10^6)	Ann.SD (m^3 * 10^6)	Q75 (m^3 * 10^6)	Ann. CV	Area (km^2)	MAR (m^3 * 10^6)	Ann.SD (m^3 * 10^6)	Q75 (m^3 * 10^6)	Ann. CV
0.00	683.17	275.02	10.87	0.40	0.00	660.72	273.39	9.93	0.41

% Zero flows = 0.0 % Zero flows = 0.0
Baseflow Parameters: A = 0.950, B = 0.43Baseflow Parameters: A = 0.950, B = 0.430
BFI = 0.37 : Hydro Index = 4.1 BFI = 0.37 : Hydro Index = 4.3

MONTH	MEAN (m^3 * 10^6)	SD (m^3 * 10^6)	CV	MONTH	MEAN (m^3 * 10^6)	SD (m^3 * 10^6)	CV
Oct	25.40	33.59	1.32	Oct	23.81	32.99	1.39
Nov	48.53	39.20	0.81	Nov	45.90	38.31	0.83
Dec	89.83	60.88	0.68	Dec	86.20	58.79	0.68
Jan	128.45	75.22	0.59	Jan	124.02	73.26	0.59
Feb	140.16	82.79	0.59	Feb	136.52	81.09	0.59
Mar	117.24	71.21	0.61	Mar	115.32	70.31	0.61
Apr	57.63	37.37	0.65	Apr	57.18	37.38	0.65
May	25.27	24.53	0.97	May	24.57	24.16	0.98
Jun	14.42	14.82	1.03	Jun	13.75	14.83	1.08
Jul	11.28	9.69	0.86	Jul	10.53	9.53	0.90
Aug	10.15	9.30	0.92	Aug	9.28	9.01	0.97
Sep	14.81	27.37	1.85	Sep	13.63	26.22	1.92

Critical months: WET : Feb, DRY : Aug
Using 20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET : 22.534, DRY : 4.010

HYDRAULICS DATA SUMMARY
Geomorph. Zone 3
Flood Zone 8
Max. Channel width (m) 51.35
Max. Channel Depth (m) 2.64

Observed Channel XS used
Observed Rating Curve used
(Gradients and Roughness n values calibrated)

Max. Gradient	0.05000
Min. Gradient	0.05000
Gradient Shape Factor	20
Max. Mannings n	2.500
Min. Mannings n	0.010
n Shape Factor	45

FLOW - STRESSOR RESPONSE DATA SUMMARY
Table of Stress weightings
Season Wet Dry

Stress at 0 FS:	9	9
FS Weight:	0	0
FI Weight:	0	0
FD Weight:	9	7

Table of initial SHIFT factors for the Stress Frequency Curves

Category	High SHIFT	Low SHIFT
A	0.000	0.055
A/B	0.000	0.082
B	0.000	0.109
B/C	0.000	0.150
C	0.000	0.330
C/D	0.000	0.510
D	0.000	0.638

Perenniality Rules
All Seasons Perennial Forced

Alignment of maximum stress to Present Day stress
Not Aligned

Table of flows (m3/2) v stress index

Stress	Wet Season Flow	Dry Season Flow
0	22.884	4.149
1	14.900	3.900
2	10.855	3.550
3	8.200	3.050
4	6.500	2.350
5	5.159	1.780
6	3.867	1.440
7	2.900	1.073
8	2.000	0.730
9	1.000	0.380
10	0.000	0.000

HIGH FLOW ESTIMATION SUMMARY DETAILS
No High flows when natural high flows are < 20% of total flows
Adjusted hydrological variability for high flows is 4.68
Maximum high flows are 190% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

Category	A	A/B	B	B/C	C	C/D	D
Annual	90.193	84.371	78.706	73.195	67.835	62.621	57.551
Oct	5.783	5.409	5.046	4.693	4.349	4.015	3.690
Nov	14.536	13.597	12.684	11.796	10.932	10.092	9.275
Dec	17.588	16.452	15.348	14.273	13.228	12.211	11.222
Jan	17.346	16.227	15.137	14.077	13.046	12.044	11.069
Feb	16.107	15.068	14.056	13.072	12.114	11.183	10.278
Mar	13.272	12.415	11.582	10.771	9.982	9.215	8.469
Apr	5.561	5.202	4.853	4.513	4.183	3.861	3.549
May	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0.000

FINAL RESERVE SUMMARY DETAILS
EWR (low and total Flows) are constrained to be below Present Day Flows

Long term mean flow requirements (Mill. m3 and %MAR)

Category	Low Flows		Total Flows	
	Mill. m3	%MAR	Mill. m3	%MAR
A	206.281	30.2	288.947	42.3
A/B	194.601	28.5	272.064	39.8
B	185.093	27.1	257.439	37.7
B/C	171.789	25.1	239.081	35.0

C	123.707	18.1	186.070	27.2
C/D	88.959	13.0	146.529	21.4
D	75.530	11.1	128.439	18.8

FLOW DURATION and RESERVE ASSURANCE TABLES

Columns are FDC percentage points:

Natural Total flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	47.674	32.134	28.458	21.960	14.660	12.672	10.764	8.346	6.872	4.524
Nov	107.568	64.836	54.358	44.058	40.590	32.576	26.044	21.114	15.540	5.743
Dec	189.596	136.184	107.880	93.044	82.830	71.918	58.452	34.040	19.552	10.177
Jan	242.110	187.168	147.668	133.096	114.600	96.368	80.444	63.976	49.826	18.135
Feb	254.900	210.134	176.320	136.858	126.470	107.830	85.520	73.286	55.258	19.815
Mar	205.972	151.506	124.078	109.834	99.560	87.124	79.994	69.644	55.008	24.905
Apr	115.124	76.068	64.568	56.678	51.580	45.744	33.178	27.792	22.470	13.351
May	35.920	28.582	25.698	22.822	19.580	18.434	16.444	13.450	11.500	7.344
Jun	22.392	16.984	14.446	12.688	11.390	10.546	9.154	7.474	6.200	3.878
Jul	23.106	14.034	10.756	10.146	8.860	7.976	6.812	4.974	4.082	2.470
Aug	16.810	12.102	10.408	9.414	8.170	7.136	5.390	4.508	3.646	2.332
Sep	25.662	18.148	11.806	10.644	8.490	7.652	6.518	5.666	3.862	2.145

Natural Baseflow flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	17.562	13.172	11.309	9.838	8.385	7.787	6.724	5.602	4.576	2.649
Nov	24.488	20.098	16.624	14.267	13.046	11.467	10.443	8.560	6.854	4.383
Dec	41.353	32.370	27.778	25.053	21.003	18.590	15.897	13.481	9.413	4.676
Jan	52.767	47.548	39.842	34.422	29.648	25.572	24.173	20.216	15.924	8.264
Feb	61.695	54.334	44.229	39.502	36.129	32.727	29.512	26.685	21.747	11.509
Mar	61.501	51.575	44.706	39.310	35.004	33.416	31.836	29.947	25.314	18.569
Apr	52.249	44.969	37.358	33.307	29.930	28.177	25.451	23.104	19.603	12.634
May	33.234	27.118	24.296	20.930	19.450	18.346	16.284	13.450	11.500	7.344
Jun	21.018	15.622	14.308	12.688	11.390	10.546	9.154	7.474	6.200	3.878
Jul	18.455	13.597	10.678	9.652	8.580	7.693	6.646	4.974	4.082	2.470
Aug	13.500	10.614	9.470	8.134	7.519	6.594	5.171	4.289	3.521	2.332
Sep	14.207	10.617	8.957	8.119	7.250	5.911	5.615	4.317	3.515	2.133

Category Low Flow Assurance curves (mill. m3)

B/C Category

	10	20	30	40	50	60	70	80	90	99
Oct	12.076	11.545	10.568	9.524	7.356	6.179	5.514	4.503	3.666	3.023
Nov	16.125	15.987	14.239	12.850	10.612	8.749	7.924	6.435	5.222	4.296
Dec	25.728	24.486	22.907	21.041	17.100	13.972	12.085	9.640	7.303	5.484
Jan	31.110	30.984	29.241	26.571	23.001	19.169	16.772	13.566	11.150	9.199
Feb	30.497	29.837	28.600	26.465	24.184	20.999	17.927	15.004	12.419	9.988
Mar	37.393	33.936	33.872	31.566	26.491	24.931	23.645	20.873	18.492	17.183
Apr	29.211	28.874	27.317	25.686	22.433	19.662	17.224	14.710	13.170	12.208
May	21.225	21.225	20.568	18.823	16.091	13.728	12.048	9.795	8.663	6.490
Jun	14.240	13.623	12.499	11.525	9.425	7.930	7.028	5.598	4.716	3.362
Jul	12.900	11.746	9.998	9.272	7.427	6.100	5.368	4.051	3.289	2.010
Aug	9.820	9.563	8.968	8.050	6.519	5.116	4.183	3.456	2.855	2.116
Sep	9.582	8.804	7.223	6.951	5.635	4.599	4.345	3.414	2.613	2.208

C/D Category

	10	20	30	40	50	60	70	80	90	99
Oct	5.612	5.402	5.045	4.755	4.095	3.906	3.735	3.274	2.900	2.597
Nov	7.392	7.354	6.695	6.323	5.762	5.370	5.224	4.575	4.048	3.597
Dec	11.088	10.833	10.338	9.932	8.825	8.053	7.591	6.603	5.518	4.562
Jan	12.926	12.909	12.515	11.982	11.152	10.276	9.754	8.707	7.903	7.713
Feb	12.084	11.999	11.840	11.566	11.134	10.511	9.700	8.901	8.150	7.510
Mar	15.890	14.939	14.879	14.865	14.864	14.862	14.695	14.127	14.118	13.900
Apr	12.214	12.208	11.824	11.585	10.855	10.349	10.036	10.029	10.021	9.844
May	9.570	9.570	9.411	9.009	8.385	7.937	7.573	6.709	6.431	6.050
Jun	6.569	6.321	5.918	5.704	5.163	4.935	4.677	4.019	3.760	3.362
Jul	5.976	5.490	4.783	4.686	4.133	3.826	3.640	2.955	2.615	2.010
Aug	4.606	4.491	4.297	4.020	3.663	3.259	2.866	2.541	2.282	2.091
Sep	4.479	4.060	3.444	3.441	3.036	3.033	2.968	2.459	2.020	1.895

Category Total Flow Assurance curves (mill. m3)

B/C Category

	10	20	30	40	50	60	70	80	90	99
Oct	20.169	18.233	16.203	14.486	12.049	10.566	9.028	6.551	3.729	3.023
Nov	36.467	32.798	28.405	25.323	22.408	19.776	16.757	11.582	5.380	4.296
Dec	50.342	44.827	40.047	36.132	31.373	27.315	22.773	15.868	7.494	5.484

Jan	55.386	51.046	46.147	41.455	37.078	32.329	27.313	19.708	11.338	9.199
Feb	53.039	48.466	44.297	40.287	37.256	33.219	27.715	20.707	12.594	9.988
Mar	55.967	49.286	46.806	42.955	37.262	34.999	31.710	25.573	18.636	17.183
Apr	36.994	35.306	32.737	30.458	26.947	23.881	20.604	16.679	13.231	12.208
May	21.225	21.225	20.568	18.823	16.091	13.728	12.048	9.795	8.663	6.490
Jun	14.240	13.623	12.499	11.525	9.425	7.930	7.028	5.598	4.716	3.362
Jul	12.900	11.746	9.998	9.272	7.427	6.100	5.368	4.051	3.289	2.010
Aug	9.820	9.563	8.968	8.050	6.519	5.116	4.183	3.456	2.855	2.116
Sep	9.582	8.804	7.223	6.951	5.635	4.599	4.345	3.414	2.613	2.208

C/D Category

Oct	12.536	11.123	9.866	9.000	8.110	7.660	6.741	5.026	2.953	2.597
Nov	24.796	21.736	18.814	16.994	15.854	14.805	12.781	8.979	4.183	3.597
Dec	32.146	28.235	25.003	22.843	21.036	19.468	16.735	11.930	5.682	4.562
Jan	33.695	30.073	26.978	24.716	23.195	21.534	18.772	13.961	8.064	7.713
Feb	31.369	27.937	25.270	23.391	22.317	20.965	18.074	13.780	8.300	7.510
Mar	31.781	28.071	25.944	24.608	24.078	23.477	21.595	18.147	14.241	13.900
Apr	18.873	17.711	16.461	15.667	14.716	13.959	12.927	11.713	10.073	9.844
May	9.570	9.570	9.411	9.009	8.385	7.937	7.573	6.709	6.431	6.050
Jun	6.569	6.321	5.918	5.704	5.163	4.935	4.677	4.019	3.760	3.362
Jul	5.976	5.490	4.783	4.686	4.133	3.826	3.640	2.955	2.615	2.010
Aug	4.606	4.491	4.297	4.020	3.663	3.259	2.866	2.541	2.282	2.091
Sep	4.479	4.060	3.444	3.441	3.036	3.033	2.968	2.459	2.020	1.895

21.6 MK_I_EWR2

DATE: 05/15/2014
Revised Desktop Model outputs for site: Mk_I_EWR2

HYDROLOGY DATA SUMMARY

```
Natural Flows:                          Present Day Flows:
   Area     MAR   Ann.SD    Q75   Ann.     Area     MAR   Ann.SD    Q75   Ann.
  (km^2)       (m^3 * 10^6)        CV     (km^2)       (m^3 * 10^6)        CV
    0.00  890.91  371.77   15.46  0.42      0.00  838.35  364.50   12.71  0.43

% Zero flows =   0.0                    % Zero flows =   0.0
Baseflow Parameters: A = 0.950, B = 0.43Baseflow Parameters: A = 0.950, B = 0.430
BFI = 0.39 : Hydro Index =   4.1        BFI = 0.37 : Hydro Index =   4.5

MONTH   MEAN      SD     CV             MONTH   MEAN      SD     CV
       (m^3 * 10^6)                            (m^3 * 10^6)
 Oct   34.99   52.16    1.49             Oct   31.20   51.11    1.64
 Nov   64.53   53.30    0.83             Nov   58.60   50.85    0.87
 Dec  117.01   83.07    0.71             Dec  110.12   77.75    0.71
 Jan  159.10   97.48    0.61             Jan  151.28   93.03    0.61
 Feb  172.79  103.70    0.60             Feb  166.46   99.70    0.60
 Mar  151.34   93.97    0.62             Mar  146.30   91.18    0.62
 Apr   79.19   52.32    0.66             Apr   75.93   51.63    0.68
 May   36.02   37.37    1.04             May   33.27   36.27    1.09
 Jun   21.30   23.04    1.08             Jun   18.89   22.74    1.20
 Jul   16.73   15.29    0.91             Jul   14.29   14.36    1.01
 Aug   14.96   13.73    0.92             Aug   12.39   12.49    1.01
 Sep   22.95   55.67    2.43             Sep   19.63   51.71    2.63
```

Critical months: WET : Feb, DRY : Sep
Using 20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET : 28.676, DRY : 6.185

HYDRAULICS DATA SUMMARY

Geomorph. Zone 3
Flood Zone 8
Max. Channel width (m) 60.48
Max. Channel Depth (m) 2.85

Observed Channel XS used
Observed Rating Curve used
(Gradients and Roughness n values calibrated)

Max. Gradient 0.02000

Min. Gradient	0.02000
Gradient Shape Factor	20
Max. Mannings n	0.200
Min. Mannings n	0.055
n Shape Factor	27

FLOW - STRESSOR RESPONSE DATA SUMMARY

Table of Stress weightings

Season	Wet	Dry
Stress at 0 FS:	9	9
FS Weight:	4	2
FI Weight:	0	0
FD Weight:	9	7

Table of initial SHIFT factors for the Stress Frequency Curves

Category	High SHIFT	Low SHIFT
A	0.000	0.058
A/B	0.000	0.086
B	0.000	0.115
B/C	0.067	0.143
C	0.200	0.172
C/D	0.133	0.200
D	0.240	0.250

Perenniality Rules
All Seasons Perennial Forced

Alignment of maximum stress to Present Day stress
Not Aligned

Table of flows (m3/2) v stress index

Stress	Wet Season Flow	Dry Season Flow
0	28.887	6.272
1	19.440	4.300
2	11.539	3.143
3	6.920	2.200
4	4.400	1.500
5	2.800	0.900
6	1.449	0.451
7	0.734	0.163
8	0.320	0.038
9	0.053	0.010
10	0.000	0.000

HIGH FLOW ESTIMATION SUMMARY DETAILS

No High flows when natural high flows are < 20% of total flows
Adjusted hydrological variability for high flows is   4.84
Maximum high flows are 190% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

Category	A	A/B	B	B/C	C	C/D	D
Annual	118.333	110.658	103.193	95.936	88.880	82.021	75.355
Oct	7.999	7.480	6.975	6.485	6.008	5.544	5.094
Nov	18.900	17.674	16.482	15.323	14.196	13.100	12.036
Dec	22.952	21.463	20.015	18.608	17.239	15.909	14.616
Jan	23.807	22.263	20.761	19.301	17.882	16.502	15.161
Feb	20.902	19.546	18.228	16.946	15.700	14.488	13.311
Mar	16.470	15.402	14.363	13.353	12.371	11.416	10.488
Apr	7.303	6.829	6.369	5.921	5.485	5.062	4.651
May	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0.000

FINAL RESERVE SUMMARY DETAILS

EWR (low and total Flows) are constrained to be below Present Day Flows

Long term mean flow requirements (Mill. m3 and %MAR)

Category	Low Flows Mill. m3	Low Flows %MAR	Total Flows Mill. m3	Total Flows %MAR
A	263.855	29.6	371.567	41.7
A/B	241.517	27.1	342.516	38.4
B	220.594	24.8	315.032	35.4
B/C	195.594	22.0	283.635	31.8
C	166.690	18.7	248.291	27.9
C/D	156.045	17.5	231.350	26.0
D	125.821	14.1	195.006	21.9

FLOW DURATION and RESERVE ASSURANCE TABLES

Columns are FDC percentage points:

Natural Total flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	62.816	43.702	36.012	28.372	21.110	16.406	14.348	12.464	9.464	6.039
Nov	146.330	82.874	68.622	60.142	53.960	41.108	31.762	27.734	21.150	7.966
Dec	241.244	181.870	141.166	118.434	103.070	87.268	70.776	43.558	26.072	12.640
Jan	300.490	236.550	184.390	164.828	146.190	113.666	98.464	78.330	62.266	20.359
Feb	327.192	266.766	198.324	174.384	151.930	133.604	103.488	95.648	64.384	24.733
Mar	281.268	200.648	156.188	143.178	124.310	115.348	102.134	94.860	74.016	33.258
Apr	159.780	108.702	81.956	76.848	68.350	61.562	48.606	41.136	30.636	18.348
May	54.858	42.414	35.442	30.694	28.550	26.554	23.462	18.800	15.434	10.207
Jun	33.252	24.982	19.640	18.066	16.420	15.194	13.116	10.792	8.990	5.918
Jul	37.342	19.364	15.600	13.718	12.710	11.344	9.520	8.006	5.992	4.178
Aug	28.010	17.570	15.030	13.300	11.780	10.078	8.270	6.600	5.516	3.636
Sep	37.356	24.346	18.594	14.702	11.950	11.026	9.950	8.308	5.844	3.227

Natural Baseflow flow duration curve (mill. m3)

	10	20	30	40	50	60	70	80	90	99
Oct	24.521	18.714	16.354	13.773	11.928	10.961	9.656	8.576	6.820	3.837
Nov	34.047	26.873	22.665	20.212	17.883	15.708	13.698	11.517	9.848	5.671
Dec	51.622	45.458	38.423	31.893	27.131	24.115	22.574	17.437	12.488	6.113
Jan	74.548	61.115	49.829	44.340	36.492	34.431	30.000	25.320	20.364	10.850
Feb	83.400	67.799	58.863	50.517	45.107	42.751	38.004	34.607	26.823	14.849
Mar	82.088	66.564	57.138	50.735	46.724	43.411	40.389	37.404	33.858	23.010
Apr	70.808	57.079	51.566	45.590	39.944	37.341	34.301	31.116	25.160	16.139
May	48.250	37.423	33.756	30.354	27.910	25.666	22.642	18.800	15.434	10.207
Jun	30.961	23.694	19.380	17.901	16.420	15.194	13.116	10.792	8.990	5.918
Jul	27.161	18.654	14.596	13.650	12.500	11.274	9.352	8.006	5.992	4.178
Aug	20.848	15.777	13.661	11.834	10.090	9.408	7.700	6.514	5.289	3.636
Sep	19.834	15.376	13.042	11.466	10.512	9.620	8.330	7.090	5.261	3.227

Category Low Flow Assurance curves (mill. m3)
B Category

	10	20	30	40	50	60	70	80	90	99
Oct	13.415	13.069	12.887	11.884	9.895	8.749	7.385	6.349	5.288	4.342
Nov	18.494	18.212	17.524	16.430	14.135	11.882	9.845	8.195	7.391	5.978
Dec	31.336	31.225	29.477	25.915	21.660	17.860	15.351	11.847	9.489	7.672
Jan	42.450	41.649	38.469	35.028	28.452	23.940	19.906	15.719	13.701	11.625
Feb	43.139	41.769	39.359	35.612	30.416	25.586	21.314	16.958	14.622	12.568
Mar	47.445	45.627	43.363	41.226	36.693	32.210	28.091	24.513	23.735	21.465
Apr	39.806	38.103	37.433	34.782	30.238	24.751	21.124	17.448	16.850	15.296
May	26.738	26.184	26.049	24.828	22.004	18.853	15.627	12.516	11.437	7.861
Jun	16.314	16.053	14.896	14.562	12.956	11.340	9.446	7.686	6.908	4.402
Jul	15.608	13.274	12.053	11.288	10.240	8.801	7.150	5.998	4.408	2.964
Aug	11.447	11.183	10.947	10.101	8.186	6.877	5.393	4.283	4.066	2.821
Sep	10.562	10.400	10.075	9.492	8.568	7.437	6.154	5.032	4.020	2.877

Category Total Flow Assurance curves (mill. m3)
B Category

	10	20	30	40	50	60	70	80	90	99
Oct	25.429	22.980	21.235	19.245	16.870	13.366	11.508	9.393	5.382	4.342
Nov	46.882	41.630	37.251	33.823	30.616	27.289	22.187	15.386	7.611	5.978
Dec	65.810	59.664	53.433	47.037	41.675	36.571	30.339	20.579	9.757	7.672
Jan	78.208	71.148	63.318	56.937	49.213	43.348	35.452	24.778	13.979	11.625
Feb	74.534	67.668	61.176	54.847	48.644	42.626	34.963	24.911	14.866	12.568
Mar	72.184	66.035	60.554	56.383	51.056	45.636	38.846	30.780	23.927	21.465
Apr	50.775	47.152	45.055	41.502	36.606	30.704	25.893	20.226	16.936	15.296

May	26.738	26.184	26.049	24.828	22.004	18.853	15.627	12.516	11.437	7.861
Jun	16.314	16.053	14.896	14.562	12.956	11.340	9.446	7.686	6.908	4.402
Jul	15.608	13.274	12.053	11.288	10.240	8.801	7.150	5.998	4.408	2.964
Aug	11.447	11.183	10.947	10.101	8.186	6.877	5.393	4.283	4.066	2.821
Sep	10.562	10.400	10.075	9.492	8.568	7.437	6.154	5.032	4.020	2.877

21.7 MK_I_EWR3

DATE: 05/15/2014
Revised Desktop Model outputs for site: Mk_I_EWR3

HYDROLOGY DATA SUMMARY

Natural Flows:					Present Day Flows:				
Area (km^2)	MAR (m^3 * 10^6)	Ann.SD (m^3 * 10^6)	Q75 (m^3 * 10^6)	Ann. CV	Area (km^2)	MAR (m^3 * 10^6)	Ann.SD (m^3 * 10^6)	Q75 (m^3 * 10^6)	Ann. CV
0.00	1068.55	459.56	19.06	0.43	0.00	983.23	445.32	14.65	0.45

% Zero flows = 0.0 % Zero flows = 0.0
Baseflow Parameters: A = 0.950, B = 0.43Baseflow Parameters: A = 0.950, B = 0.430
BFI = 0.39 : Hydro Index = 4.2 BFI = 0.37 : Hydro Index = 5.0

MONTH	MEAN (m^3 * 10^6)	SD	CV	MONTH	MEAN (m^3 * 10^6)	SD	CV
Oct	43.18	68.55	1.59	Oct	37.92	66.94	1.77
Nov	78.20	67.93	0.87	Nov	69.91	63.69	0.91
Dec	140.25	104.02	0.74	Dec	129.97	95.81	0.74
Jan	185.31	117.98	0.64	Jan	173.36	110.92	0.64
Feb	200.69	123.22	0.61	Feb	190.68	116.67	0.61
Mar	180.50	115.30	0.64	Mar	171.46	110.62	0.65
Apr	97.63	66.21	0.68	Apr	91.11	64.51	0.71
May	45.22	48.63	1.08	May	40.05	46.70	1.17
Jun	27.18	30.52	1.12	Jun	22.78	29.59	1.30
Jul	21.40	20.42	0.95	Jul	16.94	18.89	1.12
Aug	19.08	19.01	1.00	Aug	14.55	17.17	1.18
Sep	29.91	80.67	2.70	Sep	24.51	75.17	3.07

Critical months: WET : Mar, DRY : Sep
Using 20th percentile of FDC of separated baseflows
Max. baseflows (m3/s): WET : 31.828, DRY : 7.618

HYDRAULICS DATA SUMMARY

Geomorph. Zone 3
Flood Zone 8
Max. Channel width (m) 68.97
Max. Channel Depth (m) 3.03

Observed Channel XS used
Observed Rating Curve used
(Gradients and Roughness n values calibrated)

Max. Gradient	0.00100
Min. Gradient	0.01000
Gradient Shape Factor	30
Max. Mannings n	10.000
Min. Mannings n	0.030
n Shape Factor	250

FLOW - STRESSOR RESPONSE DATA SUMMARY

Table of Stress weightings

Season	Wet	Dry
Stress at 0 FS:	9	9
FS Weight:	0	0
FI Weight:	0	0
FD Weight:	9	7

Table of initial SHIFT factors for the Stress Frequency Curves

Category	High SHIFT	Low SHIFT
A	0.000	0.145

A/B	0.000	0.218
B	0.000	0.290
B/C	0.000	0.399
C	0.000	0.508
C/D	0.000	0.580
D	0.000	0.725

Perenniality Rules
All Seasons Perennial Forced

Alignment of maximum stress to Present Day stress
Not Aligned

Table of flows (m3/2) v stress index

Stress	Wet Season Flow	Dry Season Flow
0	32.619	7.867
1	28.107	5.500
2	23.500	4.300
3	19.000	3.650
4	14.500	3.129
5	10.606	2.607
6	7.600	2.086
7	4.927	1.564
8	2.900	1.043
9	1.025	0.550
10	0.000	0.000

HIGH FLOW ESTIMATION SUMMARY DETAILS
No High flows when natural high flows are < 20% of total flows
Adjusted hydrological variability for high flows is 4.20
Maximum high flows are 160% greater than normal high flows

Table of normal high flow requirements (Mill. m3)

Category	A	A/B	B	B/C	C	C/D	D
Annual	138.350	129.560	120.992	112.642	104.506	96.578	88.855
Oct	7.498	7.022	6.558	6.105	5.664	5.234	4.816
Nov	22.392	20.969	19.582	18.231	16.914	15.631	14.381
Dec	27.725	25.963	24.246	22.573	20.943	19.354	17.806
Jan	27.126	25.403	23.723	22.086	20.490	18.936	17.422
Feb	24.654	23.088	21.561	20.073	18.623	17.210	15.834
Mar	19.991	18.721	17.483	16.277	15.101	13.955	12.839
Apr	8.963	8.394	7.839	7.298	6.770	6.257	5.757
May	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0.000

FINAL RESERVE SUMMARY DETAILS
EWR (low and total Flows) are constrained to be below Present Day Flows

Long term mean flow requirements (Mill. m3 and %MAR)

Category	Low Flows		Total Flows	
	Mill. m3	%MAR	Mill. m3	%MAR
A	281.131	26.3	400.321	37.5
A/B	250.785	23.5	362.694	33.9
B	223.422	20.9	328.021	30.7
B/C	184.974	17.3	282.355	26.4
C	151.201	14.2	241.547	22.6
C/D	143.614	13.4	227.107	21.3
D	143.614	13.4	220.431	20.6

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. m3)										
Oct	80.846	53.586	42.676	31.754	24.350	20.332	17.312	15.276	11.344	7.504

Nov	168.006	102.422	85.886	70.558	63.210	48.246	36.526	31.674	25.954	9.875
Dec	305.480	215.098	164.390	138.398	121.320	97.890	79.204	51.318	29.782	14.680
Jan	346.450	286.724	220.658	191.108	156.420	130.644	111.684	91.136	68.402	22.269
Feb	378.252	298.224	231.826	201.862	172.930	156.028	121.744	108.822	71.212	28.940
Mar	336.314	234.956	185.196	168.904	148.580	132.634	123.396	108.876	86.076	39.742
Apr	197.942	142.030	99.700	90.568	83.100	73.476	60.698	49.168	37.204	21.590
May	68.642	52.124	45.192	38.692	35.640	33.152	29.180	23.646	18.338	12.655
Jun	42.240	31.646	24.872	22.156	20.730	18.768	16.394	13.538	11.374	7.652
Jul	46.944	24.788	19.342	17.168	15.590	14.156	11.974	9.608	7.488	5.549
Aug	34.162	22.840	19.184	16.360	14.650	12.074	10.200	8.460	6.724	4.747
Sep	41.618	29.628	23.356	18.624	15.490	13.360	12.466	10.460	7.556	4.118

Natural Baseflow flow duration curve (mill. m3)

Oct	31.135	22.273	20.235	16.856	15.128	13.558	12.081	10.789	8.434	4.842
Nov	43.427	33.178	28.162	25.766	21.844	19.141	16.500	14.115	12.068	6.756
Dec	66.238	55.103	46.074	37.525	32.974	29.948	25.836	20.519	15.580	7.329
Jan	89.423	72.570	60.785	52.352	43.751	39.810	34.876	30.393	23.704	13.072
Feb	99.478	77.400	70.517	59.994	54.180	50.732	44.655	39.382	30.324	17.706
Mar	99.915	83.653	67.913	60.489	56.705	52.554	47.429	44.448	39.896	25.348
Apr	85.203	71.019	62.596	55.420	48.693	45.986	40.924	37.279	29.664	19.051
May	59.003	47.242	41.586	37.093	34.930	31.038	27.327	23.646	18.196	12.655
Jun	38.133	31.336	24.542	21.988	20.730	18.768	16.394	13.538	11.374	7.652
Jul	34.227	23.832	18.134	16.946	15.530	14.108	11.878	9.608	7.488	5.549
Aug	27.744	20.906	17.059	14.781	12.720	11.483	9.800	8.228	6.616	4.747
Sep	25.645	19.693	16.059	14.386	13.190	12.310	10.312	8.869	6.623	4.118

Category Low Flow Assurance curves (mill. m3)
B Category

Oct	12.561	12.148	12.102	11.180	9.998	8.896	8.238	7.214	6.024	4.799
Nov	17.607	17.113	16.891	16.054	13.891	11.898	10.628	9.083	8.289	6.517
Dec	31.405	30.942	29.128	24.601	21.653	18.605	16.199	13.088	10.471	8.513
Jan	43.980	41.950	39.570	34.454	28.575	24.247	21.173	17.538	14.884	12.486
Feb	42.638	40.763	39.559	35.455	30.826	26.730	24.029	19.747	16.123	13.557
Mar	50.583	48.233	44.679	40.074	35.333	30.576	26.574	23.464	20.882	18.644
Apr	40.404	39.780	39.068	35.258	30.699	26.094	23.107	20.165	17.224	15.790
May	26.587	26.587	26.336	24.568	22.614	19.379	17.175	14.423	12.684	8.357
Jun	15.969	15.491	14.513	13.973	13.246	11.658	10.531	8.777	7.800	4.748
Jul	14.494	12.840	11.388	11.005	10.343	9.081	7.981	6.618	4.444	2.730
Aug	10.903	10.693	10.234	9.605	8.361	7.141	6.269	4.927	3.802	2.398
Sep	9.552	9.476	9.341	9.080	8.613	7.873	6.871	5.736	4.270	2.330

Category Total Flow Assurance curves (mill. m3)
B Category

Oct	22.315	20.624	19.595	18.018	16.556	15.026	13.148	10.075	6.112	4.799
Nov	46.734	42.423	39.267	36.476	33.473	30.204	25.292	17.627	8.551	6.517
Dec	67.469	62.281	56.834	49.886	45.900	41.271	34.355	23.667	10.796	8.513
Jan	79.265	72.613	66.677	59.194	52.298	46.423	38.937	27.888	15.202	12.486
Feb	74.708	68.631	64.196	57.940	52.387	46.885	40.174	29.155	16.412	13.557
Mar	76.587	70.831	64.657	58.306	52.816	46.920	39.666	31.092	21.116	18.644
Apr	52.063	49.911	48.025	43.433	38.538	33.421	28.976	23.585	17.329	15.790
May	26.587	26.587	26.336	24.568	22.614	19.379	17.175	14.423	12.684	8.357
Jun	15.969	15.491	14.513	13.973	13.246	11.658	10.531	8.777	7.800	4.748
Jul	14.494	12.840	11.388	11.005	10.343	9.081	7.981	6.618	4.444	2.730
Aug	10.903	10.693	10.234	9.605	8.361	7.141	6.269	4.927	3.802	2.398
Sep	9.552	9.476	9.341	9.080	8.613	7.873	6.871	5.736	4.270	2.330

22 APPENDIXD: REPORT COMMENTS

Page/ Section	Report statement	Comments	Changes made?	Authorcomment
Comments from Mmaphefo Twala: 22 August 2014				
Front pages	Department of Water Affairs	Changes to new name	Yes	
Page iii, bottom of Table	PES is set to maintain PES.	Correct so it reads ‘REC is set to maintain PES’, same comment applies for table 17.1	Yes	
Page iv, table:		Remove extra bullets in the MG EWR 5 results section.	Yes	
Page xvii. Page 1-1, par 1		DWS rather	Yes	
Page 1-1, par 4		Spelling mistake for the word **s**everal.	Yes	
Page 1-1; Page 1-3: last sentence		Reformat page and sentencing	Yes	
Page 1-3: par 1		Briefly mention what happened to the other 5 sites (12 EWR sites were selected for EWR determination of which 7 of these were assessed).	Yes	
Page 1-7		Outline of Report: this should be before chapter 1.	No	Report outline is standard for all reports in Chapter 1.
Page 19-2, section 19.2		Heading: change EFR to EWR.	Yes	